

Cosmic evolution and metal aversion in super-luminous supernova host galaxies

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ABSTRACT

The Superluminous Supernova Host galaxIES (SUSHIES) survey aims to provide strong new constraints on the progenitors of superluminous supernovae (SLSNe) by understanding the relationship to their host galaxies. Here, we present the photometric properties of 53 H-poor and 16 H-rich SLSN host galaxies out to $z \sim 4$. We model the spectral energy distributions of the hosts to derive physical properties (e.g., stellar mass and star-formation-rate distribution functions), which we compare with other established galaxy populations. At low redshift, H-poor SLSNe are preferentially found in very blue, low-mass galaxies with high average specific star-formation rates. As the redshift increases, the host population follows the general evolution of star-forming galaxies towards more luminous galaxies with higher absolute star-formation rates. After accounting for secular evolution, we find evidence for differential evolution in galaxy mass, but not in the B -band and the far UV luminosity (3σ confidence). Most remarkable is the scarcity of hosts with stellar masses above $10^{10} M_{\odot}$ for both classes of SLSNe at all redshifts. In the case of H-poor SLSNe, we attribute this to a metallicity cut-off at ~ 0.4 solar metallicity, above which the production efficiency is stifled. However, we argue that, in addition to a low metallicity, a short-lived stellar population is also required as a regulating factor for the SLSN production. Although the host population of H-rich SLSNe is very diverse, and therefore they show a weaker dependence on environmental properties, the lack of massive hosts suggests a stifled production efficiency above ~ 0.8 solar metallicity. The large dispersion of the SLSN-II_h host properties is in stark contrast to those of gamma-ray burst, ordinary core-collapse SN, and SLSN-I host galaxies. We propose that multiple progenitor channels give rise to SLSNe-II_h.

Key words: galaxies: evolution, mass function, starburst, star-formation, supernovae: general

1 INTRODUCTION

In the past decade, untargeted supernova (SN) surveys, e.g., the Palomar Transient Factory (PTF; [Law et al. 2009](#)), Pan-STARRS (PS; [Tonry et al. 2012](#)), the ROTSE SN Verification Project ([Yuan et al. 2007](#)) and the Texas SN Search ([Quimby et al. 2005](#)), discovered a new class of SNe with peak magnitudes exceeding $M_V = -21$ mag ([Gal-Yam 2012](#)), the super-luminous supernovae. These extremely lu-

minous events have been a focus of SN science ever since, because of the opportunity to study new explosion channels of very massive stars in the distant Universe ([Howell et al. 2013](#); [Cooke et al. 2012](#)), their potential use for cosmology ([Inserra & Smartt 2014](#); [Scovaccicchi et al. 2016](#)) and for studying the interstellar medium (ISM) in distant galaxies ([Berger et al. 2012](#); [Vreeswijk et al. 2014](#)). In addition, SLSNe provide a new opportunity to pinpoint star-forming galaxies independently of galaxy properties, which can ultimately lead to a better understanding of galaxy evolution at the faint-end of the luminosity and mass distribution func-

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tion (Lunnan et al. 2014; Leloudas et al. 2015c; Angus et al. 2016; Chen et al. 2016; Perley et al. 2016b).

Phenomenologically, SLSNe can be classified according to their hydrogen content into H-poor and H-rich SLSNe. The light curves of hydrogen-poor (H-poor) SLSNe, identified as a new class of transients by Quimby et al. (2011c), are ~ 3.5 mag brighter and three-times broader than ordinary stripped envelope SNe, but their intrinsic shapes are similar (e.g., Quimby et al. 2011c; Inserra et al. 2013; Nicholl et al. 2015a). Early spectra of H-poor SLSNe show a characteristic w-shaped absorption feature at ~ 4200 Å due to oxygen in the ejecta (Quimby et al. 2011c) that is usually not seen in Type Ibc SNe (e.g., Modjaz et al. 2009). About a month after the maximum, the ejecta cool down to temperatures typical of ordinary Type Ibc SNe at maximum light. At that point, SLSN spectra also exhibit absorption features similar to Type Ibc SNe (e.g., Pastorello et al. 2010; Inserra et al. 2013; Nicholl et al. 2014).

A subgroup of H-poor SLSNe shows exceptionally broad light curves ($\tau_{\text{rise}} > 25$ days, $\tau_{\text{decay}} > 50$ days; Nicholl et al. 2015a), hereafter called slow-declining SLSN-I. In some cases the decay slope is comparable to that of the radioactive decay of ^{56}Ni . Gal-Yam et al. (2009) argued that in the case for SN2007bi the supernova was powered by the radioactive decay of several solar masses of ^{56}Ni (Gal-Yam 2012), synthesised during a pair-instability SN (PISN) of a star with $M_{\text{ZAMS}} \sim 200 M_{\odot}$ (e.g., Fowler & Hoyle 1964; Barkat et al. 1967; Bisnovatyi-Kogan & Kazhdan 1967; Rakavy & Shaviv 1967; Fraley 1968; Heger et al. 2003; Woosley et al. 2007). However, the SN was discovered only shortly before the SN reached its maximum. Information about the rise time were not available, which are critical to distinguish between SN models. The well-sampled SLSNe PTF12dam and PS1-11ap, which were spectroscopically similar to SN2007bi at late times, had rise times that were incompatible with PISN models (Nicholl et al. 2013). This also casted doubt on the PISN interpretation of SN2007bi. Recent findings by Kozlyeva et al. (2016) showed that PISN models can indeed predict short rise times similar to that of PTF12dam, while current models for PISN spectra are incompatible with the spectra of PTF12dam and SN2007bi (Jerkstrand et al. 2016).

The energy source powering H-poor SLSNe is highly debated. The most discussed models include magnetars formed during the collapse of massive stars (e.g., Kasen & Bildsten 2010; Inserra et al. 2013), the interaction of the SN ejecta with dense H-deficient circumstellar material (CSM) expelled by the progenitor prior to the explosion (Woosley et al. 2007; Blinnikov & Sorokina 2010; Chevalier & Irwin 2011; Chatzopoulos & Wheeler 2012; Quataert & Shiode 2012; Sorokina et al. 2016), PISNe, and pulsational PISNe (e.g., Woosley et al. 2007; Yan et al. 2015).

Hydrogen-rich (H-rich) SLSNe are characterised by an initial blue continuum and narrow Balmer lines, similar to classical Type IIn SNe (Schlegel 1990; Filippenko 1997; Kiewe et al. 2012) that are powered by the interaction of the supernova with its circumstellar material (e.g., Chevalier & Irwin 2011). However, recent observations suggest a richer phenomenology. Spectra of the SNe 2008es and 2013hx showed broad H α emission components and linear declines after maximum, similar to normal IIL SNe (Gezari et al. 2009; Miller et al. 2009; Inserra et al. 2016). An-

other intriguing object is CSS121015:004244+132827 (hereafter CSS121015). It firstly evolved as a H-poor SN but at 49 days after the maximum, its spectrum showed broad and narrow H α emission lines (Benetti et al. 2014). These supernovae are not powered by interaction with circum-stellar material in contrast to SLSN-IIn. Hereafter we call this subclass SLSN-II.

The possible diversity of SLSN progenitors suggests zero-age-main-sequence (ZAMS) masses up to a few hundred solar masses. Given their characteristic distance scale, a direct search for their progenitors is unfeasible. Alternatively, host observations have the potential to indirectly provide constraints on the progenitor population. The first systematic study of a sample of 17 H-poor and -rich SLSNe by Neill et al. (2011) pointed to low-mass galaxies with high specific star-formation rates between 10^{-8} and 10^{-9} yr^{-1} , though with very large uncertainties because of the limited wavelength coverage. This initial finding was supported by individual studies of the hosts of SN2010gx (Chen et al. 2013) and PS1-10bj (Lunnan et al. 2013). Their spectroscopic observations also showed that both events occurred in low-metallicity galaxies with $Z < 0.4 Z_{\odot}$.

A survey of 31 H-poor SLSN host galaxies by Lunnan et al. (2014) consolidated the picture of H-poor SLSNe exploding in sub-luminous low-mass dwarf galaxies with median specific star-formation rates of $2 \times 10^{-9} \text{ yr}^{-1}$. Furthermore, the preference for galaxies with a median metallicity of $Z \sim 0.5 Z_{\odot}$ hints to a stifled production efficiency at high metallicity. Perley et al. (2016b) confirmed this trend by modelling the mass function of 18 SLSN-I hosts at $z < 0.5$ from the PTF survey (see also Chen et al. 2016). *Hubble Space Telescope* observations of 11 hosts of H-poor SLSNe by Lunnan et al. (2015) revealed that H-poor SLSNe are correlated with UV light but not as tightly as long-duration gamma-ray bursts (GRBs; see also Angus et al. 2016; Blanchard et al. 2016), which are also connected with the death of massive stars (e.g. Woosley 2012). Furthermore, the inter-stellar medium of SLSN-I host galaxies is characterised by on average significantly weaker absorption lines than GRBs (Vreeswijk et al. 2014).

In 2012, we initiated the SUPERLUMINOUS SUPERNOVA Host galaxIES (SUSHIES) survey (Leloudas et al. 2015c) to characterise a large set of host galaxies of H-poor and H-rich SLSNe over a large redshift range. The goals of this survey are to study SLSN host galaxies in context of other star-forming galaxies and to place constraints on the nature of their progenitors. To achieve this, our survey has spectroscopic and imaging components to characterise the integrated host properties, such as mass, metallicity, star-formation rate, age of the stellar populations and dust attenuation.

In the first SUSHIES sample paper, Leloudas et al. (2015c) discussed the spectroscopic properties of 17 H-poor and 8 H-rich SLSN host galaxies. We showed that the host galaxies of H-poor SLSNe are characterised by hard ionisation fields, low metallicity and very high specific star-formation rates. A high number ($\sim 50\%$) of H-poor SLSNe at $z < 0.5$ occurred in extreme emission-line galaxies (e.g., Atek et al. 2011; Amorín et al. 2014, 2015), which represent a short-lived phase in galaxy evolution following an intense starburst. Moreover, in Thöne et al. (2015) we performed spatially resolved spectroscopy of the host of PTF12dam,

the most extreme host galaxy in the sample with high signal to noise, and found strong evidence for a very young stellar population at the explosion site with an age of ~ 3 Myr. These findings let us to conclude in [Leloudas et al. \(2015c\)](#) that SLSN progenitors are possibly the very first stars to explode in a starburst, at an earlier evolutionary stage than GRB progenitors. Therefore, not only metallicity but also age is likely a critical condition for the production of SLSN progenitors. [Chen et al. \(2016\)](#) and [Perley et al. \(2016b\)](#) questioned the importance of the age and proposed that metallicity is the primary factor for the SLSN progenitors.

While H-poor SLSN are preferentially found in rather extreme environments, the findings by [Leloudas et al. \(2015c\)](#) and [Perley et al. \(2016b\)](#) point to a weaker dependence on environment properties for H-rich SLSNe, e.g. a higher average metallicity, softer ionisation states.

In this second sample paper of the SUSHIES survey, we present photometric data of a sample of 53 H-poor and 16 H-rich SLSN host galaxies, including almost every SLSN reported in the literature and detected before 2015, therefore more than doubling the largest sample of SLSN host galaxies discussed to date ([Perley et al. 2016b](#)). The scope of this paper is to provide distribution functions of physical properties, such as luminosities, masses of the stellar populations and star-formation rates, investigate their redshift evolution and compare these results to other samples of starburst galaxies.

Throughout the paper, we adopt a Planck Cosmology, i.e., $\Omega_m = 0.315$, $\Omega_\Lambda = 0.685$, $H_0 = 67.3 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ([Planck Collaboration 2014](#)). Uncertainties and dispersions are quoted at 1σ confidence. We refer to the solar abundance compiled in [Asplund et al. \(2009\)](#).

2 SAMPLE DEFINITION, OBSERVATIONS AND DATA REDUCTION

2.1 Sample definition

Among all SLSNe reported in the literature (~ 110), we selected those that were discovered until the end of 2014 and announced before April 2015. Therefore, many of the SLSNe published recently by [Perley et al. \(2016b\)](#) are not included here. In addition, we screened the Asiago Supernova catalogue ([Barbon et al. 2010](#)) for objects with an absolute magnitude of significantly brighter than $M = -21$ mag and spectroscopic information. This revealed two additional H-poor SLSNe 2009de and 2011ep ([Drake et al. 2009b](#); [Moskvitin et al. 2010](#); [Graham et al. 2011a](#)) and two H-rich SLSNe 2009nm and SN2011cp ([Drake et al. 2009c](#); [Christensen et al. 2009](#); [Drake et al. 2011c,d](#); [Graham et al. 2011b](#)). Their properties are summarised in Table 1.

Our sample comprises of 53 H-poor and 16 H-rich SLSNe. The H-poor sample includes 7 slow-declining H-poor SLSNe, while the H-rich sample includes the SLSNe-II CSS121015, SN2008es and SN2013hx. Figure 1 displays the redshift distribution of our sample. It covers a redshift interval from $z \sim 0.1$ to $z \sim 2$ with a singular object at $z \sim 4$. The redshift distribution of the H-poor sample covers the full range and has a median of $\bar{z} = 0.46$. The H-rich sample only extends to $z \sim 0.4$ and has a median of $\bar{z} = 0.21$.

2.2 Observations

A fundamental goal of our survey is to secure multi-band data from the rest-frame UV to NIR, to model the spectral energy distributions of the host galaxies. To ensure a sufficient wavelength coverage and data quality, we aimed to have at least one observation of the rest-frame UV and of the NIR and two observations of the rest-frame optical, if a galaxy was brighter than $r < 24$ mag.

To optimise the observing campaign, we queried the VizieR database ([Ochsenbein et al. 2000](#)) and public archives for available catalogues and data, such as the ESO, Gemini and Subaru archives. Our primary source catalogues are from the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS; [Hudelot et al. 2012](#)), the Cosmological Evolution Survey (COSMOS; [Scoville et al. 2007](#)), the Galaxy Evolution Explorer (GALEX; [Martin et al. 2005](#)), the Sloan Digital sky survey (SDSS; [York et al. 2000](#)), the UKIRT Infrared Deep Sky Survey (UKIDSS; [Lawrence et al. 2007](#)) and the Wide-field Infrared Survey Explorer (WISE; [Wright et al. 2010](#)).¹ These catalogues were complemented by the Coma Cluster catalogue ([Adami et al. 2006](#)), the UltraVISTA catalogue ([McCracken et al. 2012](#)), the VISTA Deep Extragalactic Observations survey (VIDEO; [Jarvis et al. 2013](#)) and the VIRMOS deep imaging survey (VIRMOS; [Le Fèvre et al. 2004](#)). Furthermore, we incorporated measurements previously reported in [Inserra et al. \(2013\)](#), [Lunnan et al. \(2014\)](#), [Nicholl et al. \(2014\)](#), [Vreeswijk et al. \(2014\)](#) and [Angus et al. \(2016\)](#).

Between 2012 and 2016, we used observing proposals at the 6.5-m Magellan/Baade Telescope (PI: Schulze, Kim),² the 8.2-m ESO-VLT (PI: Leloudas, Krühler),³ the 10.4-m GTC and 3.5-m CAHA telescope (PI: Gorosabel) and the 0.3-m UV/Optical Telescope (UVOT; [Romig et al. 2005](#)) onboard the *Swift* satellite ([Gehrels et al. 2004](#), PI: Leloudas) to obtain rest-frame UV, optical and NIR data. In the subsequent sections, we briefly summarise each campaign.

Our Magellan campaign was performed between 2012 and 2016 with the 6.5-m Baade telescope equipped with the optical wide-field Inamori-Magellan Areal Camera and Spectrograph (IMACS; [Dressler et al. 2011](#)), the Parallel Imager for Southern Cosmological Observations (PISCO; [Stalder et al. 2014](#)), and the near-infrared (NIR) camera FourStar ([Persson et al. 2013](#)). The optical data were secured in $g'r'i'z'$, primarily with the IMACS f/2 camera, but also with the IMACS f/4 camera and PISCO. The near infrared observations were performed in J and K_s .

The ESO VLT observations were taken in visitor and service mode. The visitor run took place between 29 May and 2 June 2013. We used the Focal Reducer and Spectrograph 2 instrument (FOR2; [Appenzeller et al. 1998](#)), equipped with the red-sensitive CCD to secure data in $uBgVRIz$. In addition, we obtained J and K band imaging with the High Acuity Wide field K-band Imager (HAWK-I;

¹ We included WISE data of only a few hosts.

² Programme IDs: CN2013A-195, CN2013B-70, CN2014A-114, CN2014B-127, CN2014B-102, CN-2015A-129, CN2015A-143, CN-2015B-87, CN2015B-99, CN2016A-108, and CN2016B-98

³ Programme IDs: 089.D-0902, 091.A-0703, 091.D-0734, and 290.D-5139

Table 1. Key properties of the super-luminous supernovae in our sample

Object	R. A. (J2000)	Dec. (J2000)	Redshift	Type	$E(B - V)_{\text{Gal.}}$ (mag)	Decline time scale τ_{dec} (days)	Reference
Spectroscopic dample (23)							
PS1-10bzj	03:31:39.83	-27:47:42.2	0.649	SLSN-I	0.01	37.3 (fast)	[1, 2]
PS1-11ap	10:48:27.73	+57:09:09.2	0.524	SLSN-I	0.01	87.9 (slow)	[2, 3]
PTF09cnd	16:12:08.94	+51:29:16.1	0.258	SLSN-I	0.02	75.3 (slow)	[2, 4]
PTF10heh	12:48:52.04	+13:26:24.5	0.338	SLSN-II _{in}	0.02	...	[5]
PTF10hgi	16:37:47.04	+06:12:32.3	0.099	SLSN-I	0.07	35.6 (fast)	[2, 6, 7]
PTF10qaf	23:35:42.89	+10:46:32.9	0.284	SLSN-II _{in}	0.07	...	[8]
PTF10vqv	03:03:06.84	-01:32:34.9	0.452	SLSN-I	0.06	...	[9]
PTF11dsf	16:11:33.55	+40:18:03.5	0.385	SLSN-II _{in}	0.01	...	[10]
PTF12dam	14:24:46.20	+46:13:48.3	0.107	SLSN-I	0.01	72.5 (slow)	[2, 11]
SN1999as	09:16:30.86	+13:39:02.2	0.127	SLSN-I	0.03	...	[8, 12]
SN1999bd	09:30:29.17	+16:26:07.8	0.151	SLSN-II _{in}	0.03	...	[8, 13]
SN2006oz	22:08:53.56	+00:53:50.4	0.396	SLSN-I	0.04	...	[14]
SN2006tf ¹	12:46:15.82	+11:25:56.3	0.074	SLSN-II _{in}	0.02	...	[15]
SN2007bi ²	13:19:20.00	+08:55:44.0	0.128	SLSN-I	0.02	84.5 (slow)	[2, 16, 17]
SN2008am	12:28:36.25	+15:35:49.1	0.233	SLSN-II _{in}	0.02	...	[18]
SN2009jh ³	14:49:10.08	+29:25:11.4	0.349	SLSN-I	0.01	60.6 (slow)	[2, 4]
SN2010gx ⁴	11:25:46.71	-08:49:41.4	0.230	SLSN-I	0.03	29.1 (fast)	[2, 4, 19]
SN2010kd	12:08:01.11	+49:13:31.1	0.101	SLSN-I	0.03	...	[20, 21]
SN2011ke ⁵	13:50:57.77	+26:16:42.8	0.143	SLSN-I	0.01	25.7 (fast)	[2, 6]
SN2011kf ⁶	14:36:57.53	+16:30:56.6	0.245	SLSN-I	0.02	28.5 (fast)	[2, 6]
SN2012il ⁷	09:46:12.91	+19:50:28.7	0.175	SLSN-I	0.02	23.2 (fast)	[2, 6]
SNLS06D4eu	22:15:54.29	-18:10:45.6	1.588	SLSN-I	0.02	...	[22]
SSS120810 ⁸	23:18:01.82	-56:09:25.7	0.156	SLSN-I	0.02	30.2 (fast)	[2, 23]
Non-spectroscopic sample (46)							
CSS100217 ⁹	10:29:12.56	+40:42:20.0	0.147	SLSN-II _{in}	0.01	...	[24]
CSS121015 ¹⁰	00:42:44.34	+13:28:26.5	0.286	SLSN-II	0.07	37.8 (fast)	[2, 25]
CSS140925 ¹¹	00:58:54.11	+18:13:22.2	0.460	SLSN-I	0.06	...	[26]
DES14S2qri	02:43:32.14	-01:07:34.2	1.500	SLSN-I	0.03	...	[27]
DES14X2byo	02:23:46.93	-06:08:12.3	0.869	SLSN-I	0.03	...	[28]
DES14X3taz	02:28:04.46	-04:05:12.7	0.608	SLSN-I	0.02	...	[29]
iPTF13ajg	16:39:03.95	+37:01:38.4	0.740	SLSN-I	0.01	62.0 (slow)	[2, 30]
LSQ12dlf ¹²	01:50:29.80	-21:48:45.4	0.255	SLSN-I	0.01	35.4 (fast)	[2, 23]
LSQ14an	12:53:47.83	-29:31:27.2	0.163	SLSN-I	0.07	...	[31]
LSQ14mo	10:22:41.53	-16:55:14.4	0.2561	SLSN-I	0.06	27.3 (fast)	[2, 32]
LSQ14bdq	10:01:41.60	-12:22:13.4	0.345	SLSN-I	0.06	71.2 (slow)	[2, 33]
LSQ14fxj	02:39:12.61	+03:19:29.6	0.360	SLSN-I	0.03	...	[34]
MLS121104 ¹³	02:16:42.51	+20:40:08.5	0.303	SLSN-I	0.15	...	[35, 36]
PS1-10ky	22:13:37.85	+01:14:23.6	0.956	SLSN-I	0.03	32.5 (fast)	[2, 37]
PS1-10pm	12:12:42.20	+46:59:29.5	1.206	SLSN-I	0.02	...	[38]
PS1-10ahf	23:32:28.30	-00:21:43.6	1.100	SLSN-I	0.03	...	[38]
PS1-10awh	22:14:29.83	-00:04:03.6	0.909	SLSN-I	0.07	...	[37]
PS1-11tt	16:12:45.78	+54:04:17.0	1.283	SLSN-I	0.01	...	[39]
PS1-11afv	12:15:37.77	+48:10:48.6	1.407	SLSN-I	0.01	...	[39]
PS1-11aib	22:18:12.22	+01:33:32.0	0.997	SLSN-I	0.04	...	[39]
PS1-11bam	08:41:14.19	+44:01:57.0	1.565	SLSN-I	0.02	...	[40]
PS1-11bdn	02:25:46.29	-05:06:56.6	0.738	SLSN-I	0.02	...	[39]
PS1-12zn	09:59:49.62	+02:51:31.9	0.674	SLSN-I	0.02	...	[39]
PS1-12bmy	03:34:13.12	-26:31:17.2	1.566	SLSN-I	0.01	...	[39]
PS1-12bqf	02:24:54.62	-04:50:22.7	0.522	SLSN-I	0.02	...	[39]
PS1-13gt	12:18:02.03	+47:34:46.0	0.884	SLSN-I	0.02	...	[39]
PTF09atu	16:30:24.55	+23:38:25.0	0.501	SLSN-I	0.04	...	[4]
PTF11rks	01:39:45.51	+29:55:27.0	0.190	SLSN-I	0.04	22.3 (fast)	[2, 6, 41]
SCP06F6	14:32:27.40	+33:32:24.8	1.189	SLSN-I	0.01	39.8 (fast)	[2, 42]
SN2003ma	05:31:01.88	-70:04:15.9	0.289	SLSN-II _{in}	0.31	...	[43]
SN2005ap	13:01:14.83	+27:43:32.3	0.283	SLSN-I	0.01	28.8 (fast)	[2, 44]
SN2006gy	03:17:27.06	+41:24:19.5	0.019	SLSN-II _{in}	0.14	...	[45]
SN2007bw ¹⁴	17:11:01.99	+24:30:36.4	0.140	SLSN-II _{in}	0.04	...	[46]
SN2008es ¹⁵	11:56:49.13	+54:27:25.7	0.205	SLSN-II	0.01	38.0 (fast)	[2, 47, 48]
SN2008fz ¹⁶	23:16:16.60	+11:42:47.5	0.133	SLSN-II _{in}	0.04	...	[49]
SN2009de ¹⁷	13:00:37.49	+17:50:57.0	0.311	SLSN-I	0.04	...	[50, 51, 52]
SN2009nm ¹⁸	10:05:24.54	+51:16:38.7	0.210	SLSN-II _{in}	0.01	...	[53, 54]

Table 1 – *continued* Key properties of the super-luminous supernovae in our sample

Object	R. A. (J2000)	Dec. (J2000)	Redshift	Type	$E(B - V)$ (mag)	Decline time τ_{dec} (days)	Reference
SN2011cp ¹⁹	07:52:32.61	+21:53:29.7	0.380	SLSN-IIIn	0.05	...	[55]
SN2011ep ²⁰	17:03:41.78	+32:45:52.6	0.280	SLSN-I	0.02	...	[56]
SN2013dg ²¹	13:18:41.38	−07:04:43.1	0.265	SLSN-I	0.04	30.7 (fast)	[2, 23]
SN2013hx ²²	01:35:32.83	−57:57:50.6	0.130	SLSN-II	0.02	33.6 (fast)	[2, 57]
SN2013hy ²³	02:42:32.82	−01:21:30.1	0.663	SLSN-I	0.03	...	[58]
SN2015bn ²⁴	11:33:41.57	+00:43:32.2	0.110	SLSN-I	0.02	...	[59]
SN1000+0216 [†]	10:00:05.87	+02:16:23.6	3.899	SLSN-I	0.02	...	[60]
SN2213-1745	22:13:39.97	−17:45:24.5	2.046	SLSN-I	0.02	...	[60]
SNLS07D2bv	10:00:06.62	+02:38:35.8	~ 1.5	SLSN-I	0.02	...	[22]

Note. — The coordinates refer to the positions of the supernovae. The Galactic extinction measurements were taken from [Schlafly & Finkbeiner \(2011\)](#). We divided the sample into the spectroscopic sample (23 objects) presented in [Leloudas et al. \(2015c\)](#) and in a non-spectroscopic sample (46 objects). The decay-time scale τ_{dec} is defined as the time when the luminosity of the pseudo-bolometric *griz* light curve dropped to L_{max}/e . We divide the sample into fast and slow decliners if $\tau_{\text{dec}} < 50$ and > 50 days, respectively.

[†] The classification of SN1000+0213 relies on photometry. Due to the detection of a bump before the main emission (for details see [Leloudas et al. 2012](#); [Nicholl et al. 2015a](#)), we put the SN in the SLSN-I class.

Alternative SN names: ¹ CSS070320:124616+112555; ² SNF20070406-008; ³ CSS090802:144910+292510, PTF09cwl; ⁴ CSS100313:112547-084941, PTF10cwr; ⁵ CSS110406:135058+261642, PTF11dij, PS1-11xk; ⁶ CSS111230:143658+163057; ⁷ CSS120121:094613+195028, PS1-12fo; ⁸ SSS120810:231802-560926; ⁹ CSS100217:102913+404220; ¹⁰ CSS121015:004244+132827; ¹¹ CSS140925:005854+181322; ¹² SSS120907-015030-214847; ¹³ MLS121104:021643+204009, LSQ12fzb; ¹⁴ SNF20070418-020; ¹⁵ ROTSE3 J115649.1+542725; ¹⁶ CSS080922:231617+114248; ¹⁷ CSS090102:130037+175057, PSN K0901-1; ¹⁸ CSS091120:100525+511639; ¹⁹ MLS110426:075233+215330, PSN J07523261+2153297; ²⁰ CSS110414:170342+324553; ²¹ CSS130530:131841-070443, MLS130517:131841-070443; ²² SMT J013533283-5757506; ²³ DES13S2cmm; ²⁴ CSS141223-113342+004332, MLS150211-113342+004333, PS15ae

References. — [1]: [Lunnan et al. \(2013\)](#); [1]: [Nicholl et al. \(2015a\)](#); [3]: [McCrum et al. \(2014\)](#); [4]: [Quimby et al. \(2011c\)](#); [5]: [Quimby et al. \(2010a\)](#); [6]: [Inserra et al. \(2013\)](#); [7]: [Leloudas et al. \(2015c\)](#); [8]: [Gal-Yam \(2012\)](#); [9]: [Quimby et al. \(2010b\)](#); [10]: [Quimby et al. \(2011a\)](#); [11]: [Nicholl et al. \(2013\)](#); [12]: [Knop et al. \(1999\)](#); [13]: [Nugent et al. \(1999\)](#); [14]: [Leloudas et al. \(2012\)](#); [15]: [Smith et al. \(2008\)](#); [16]: [Gal-Yam et al. \(2009\)](#); [17]: [Young et al. \(2010\)](#); [18]: [Chatzopoulos et al. \(2011\)](#); [19]: [Pastorello et al. \(2010\)](#); [20]: [Vinko et al. \(2012\)](#); [21]: [Quimby et al. \(2013\)](#); [22]: [Howell et al. \(2013\)](#); [23]: [Nicholl et al. \(2014\)](#); [24]: [Drake et al. \(2011a\)](#); [25]: [Benetti et al. \(2014\)](#); [26]: [Campbell et al. \(2014\)](#); [27]: [Castander et al. \(2015\)](#); [28]: [Graham et al. \(2014\)](#); [29]: [Smith et al. \(2016\)](#); [30]: [Vreeswijk et al. \(2014\)](#); [31]: [Leget et al. \(2014\)](#); [32]: [Leloudas et al. \(2015b\)](#); [33]: [Nicholl et al. \(2015b\)](#); [34]: [Smith et al. \(2014\)](#); [35]: [Drake et al. \(2012\)](#); [36]: [Fatkhullin & Gabdееv \(2012\)](#); [37]: [Chomiuk et al. \(2011\)](#); [38]: [McCrum et al. \(2015\)](#); [39]: [Lunnan et al. \(2014\)](#); [40]: [Berger et al. \(2012\)](#); [41]: [Quimby et al. \(2011b\)](#); [42]: [Barbary et al. \(2009\)](#); [43]: [Rest et al. \(2011\)](#); [44]: [Quimby et al. \(2007\)](#); [45]: [Smith et al. \(2007\)](#); [46]: [Agnoletto \(2010\)](#); [47]: [Gezari et al. \(2009\)](#); [48]: [Miller et al. \(2009\)](#); [49]: [Drake et al. \(2010\)](#); [50]: [Drake et al. \(2009b\)](#); [51]: [Drake et al. \(2009a\)](#); [52]: [Moskvitin et al. \(2010\)](#); [53]: [Drake et al. \(2009c\)](#); [54]: [Christensen et al. \(2009\)](#); [55]: [Drake et al. \(2011b\)](#); [56]: [Graham et al. \(2011a\)](#); [57]: [Inserra et al. \(2016\)](#); [58]: [Papadopoulos et al. \(2015\)](#); [59]: [Nicholl et al. \(2016\)](#) [60]: [Cooke et al. \(2012\)](#);

[Pirard et al. 2004](#); [Casali et al. 2006](#); [Kissler-Patig et al. 2008](#)). Additional optical and NIR data were obtained with FORS2, the Infrared Spectrometer And Array Camera (ISAAC; [Moorwood et al. 1998](#)) and HAWK-I in queue mode.

The CAHA and GTC campaigns primarily focused on targets on the northern hemisphere. The CAHA observing programme was carried out with the 4-channel Bonn University Simultaneous Camera (BUSCA; [Reif et al. 1999](#)) in $u'g'r'i'$ at the 3.5-m CAHA telescope in 2012. We also used the infrared wide-field camera Omega2000 ([Kovács et al. 2004](#)) to secure J and K band observations between 2013 and 2015 and also in Y and H band for a few targets. The objective of the campaign at the 10.4-m GTC telescope was to secure deep imaging of SNe 2008es and 2009jh with the Optical System for Imaging and low-Intermediate-Resolution Integrated Spectroscopy (OSIRIS; [Cepa et al. 2000](#)) camera.

Rest-frame UV data are critical to break degeneracies in the SED modelling. For objects at $z < 0.4$, observations

in U or bluer filters are needed to probe the UV. *GALEX* provided critical rest-frame UV data for most objects. In addition, we secured UV photometry of five fields with the UV/optical telescope UVOT on board the *Swift* satellite in 2014 and incorporated archival UVOT data of a further SLSN.

These core observing campaigns were complemented by smaller observing programmes that targeted selected host galaxies. We observed the field of SNe 2005ap with the Andalusia Faint Object Spectrograph and Camera (ALFOSC) at the 2.54-m Nordic Optical Telescope and the field of SN2007bi with ALFOSC and the 7-channel imager Gamma-Ray Burst Optical/Near-Infrared Detector (GROND; [Greiner et al. 2008](#)) at the 2.2-m Max-Planck-Gesellschaft telescope.

To constrain the total star-formation rate, we used 1.4 GHz data from the VLA Faint Images of the Radio Sky at Twenty-Centimeters (FIRST; [Becker et al. 1995](#)), the NRAO VLA Sky Survey (NVSS, $\nu = 1.4$ GHz; [Condon et al. 1998](#)), and 843 MHz data from the Sydney Univer-

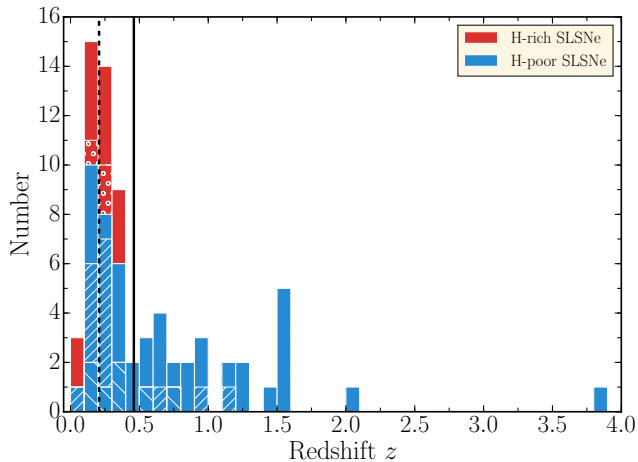


Figure 1. The redshift distribution of the SUSHIES survey. For 21 H-poor SLSNe, information about the decline time-scale are in hand. The region hatched by ‘//’ displays the redshift distribution of the fast-decliners and the region highlighted by ‘\’ the redshift distribution of the slow-decliners. The redshift distribution of the three SLSNe-II CSS121015, SN2008es and SN2013hx are highlighted by ‘o’. The median redshifts of the H-poor and H-rich sample are $\bar{z} = 0.46$ (solid vertical line) and $\bar{z} = 0.21$ (dashed vertical line), respectively.

sity Molonglo Sky Survey (SUMSS; Bock et al. 1999). In addition, we secured continuum observations of MLS121104, SN2005ap and SN2008fz with the Karl Jansky Very Large Array (JVLA; PI: Ibar).⁴ The continuum observations were performed in L band in the most extended A-configuration in July and September 2015. The frequency was centred at 1.5 GHz with a total synthesised bandwidth of 1 GHz. We used the standard flux and bandwidth calibrator 3C48 for all the sources except SN2005ap, for which we used 3C286 instead. For phase calibration purposes we used bright nearby point-like sources from the VLA calibrator list (MLS121104: J0238+1636, SN2005ap: J1310+3220 and SN2008fz: J2330+1100). The key properties of each observation is reported in Tables A1.

2.3 Data reduction

We reduced all data in a consistent way with standard routines in IRAF (Tody 1986). The typical steps are i) bias/overscan subtraction, ii) flat-fielding, iii) fringe correction, iv) stacking of individual images and v) astrometric calibration. For a few instruments we used instrument specific software packages: the GEMINI IRAF package, the GROND pipeline (Yoldaş et al. 2008; Krühler et al. 2008), PHOTPIPE for PISCO data (Bleem et al. 2015), SDFRED1 and SDFRED2 for Subaru Suprime-Cam data (Yagi et al. 2002; Ouchi et al. 2004), THELI version 2.10.0 (Erben et al. 2005; Schirmer 2013) for the FourStar data, VLT instrument pipelines for HAWK-I (version 1.8.18) and ISAAC (version 6.1.3) data,⁵ and a customised pipeline for the Magellan/IMACS data. The world-coordinate system was calibrated with astrometry.net version 0.5 (Lang et al. 2010).

UVOT data were retrieved from the *Swift* Data Archive.⁶ We used the standard UVOT data analysis software distributed with HEASOFT version 6.12, along with the standard calibration data.⁷

The JVLA data were reduced using the Common Astronomy Software Applications package (CASA; McMullin et al. 2007) and consisted of careful data flagging and standard flux, bandwidth and phase calibration. No self-calibration was performed to the data. The obtained flux density root mean square (r.m.s.) noise of the images are shown in Table A2.

3 METHODS

3.1 Host identification

We aligned our host-only images with the original SN images that we retrieved from archives with Gaia version 4.4.6.⁸ The average alignment accuracy was $\sim 0''.17$. However, we did not find (suitable) public data for 13 SNe from PanSTARRS, and neither for SNe 2006tf, 2009de, 2009nm and 2011cp (in total 17/69 objects). For those objects we relied on the reported SN positions. Although this added an uncertainty to the host identification, the SN positions always coincided with a galaxy, which we assume to be the host galaxy.

3.2 Photometry

We developed a Python programme that is based on Source Extractor version 2.19.5 (Bertin & Arnouts 1996) to perform seeing matched aperture photometry. The source radius was typically 2–4 times the full-width at half maximum (FWHM) of the stellar PSF, to measure the total flux of the given object. In case another object was close to the SN position or if the host had a large angular diameter, we adjusted the extraction radius accordingly. If a host evaded detection in all bands, we measured the nominal flux and its uncertainty at the SN position using an aperture with a radius of $4 \times \text{FWHM}$.

Once an instrumental magnitude was established, it was photometrically calibrated against the brightness of several standard stars measured in a similar manner or tied to the SDSS DR8 (Aihara et al. 2011) and the AAVSO (American Association of Variable Star Observers) Photometric All-Sky Survey (APASS) DR9 (Henden et al. 2016) catalogues. For Bessell/Johnson/Cousins filters, we converted the photometry of stars in the SDSS catalogue from SDSS using the Lupton colour equations.⁹ In the NIR (JHK_s), the photometry was tied to 2MASS. The UVOT photometry was performed with the programme uvotsource. UVOT zero-points are defined for an aperture with a diameter of $5''$. We translated these zeropoints into those of our requested apertures by applying simple aperture correction methods for stars.

Finally, the measurements were corrected for Galactic extinction using the extinction maps by Schlafly &

⁴ Programme ID: 15A-224

⁵ <http://www.eso.org/sci/software/cpl/esorex.html>

⁶ http://www.swift.ac.uk/swift_portal/

⁷ <http://heasarc.nasa.gov/lheasoft/>

⁸ <http://starlink.eao.hawaii.edu/starlink/2015ADownload>

⁹ <http://www.sdss.org/dr5/algorithms/sdssUBVRITransform.html>

Finkbeiner (2011) and transformed into the AB system using Blanton & Roweis (2007) and Breeveld et al. (2011).

In total, we measured the brightness of 53 of the 69 objects, which also includes the re-evaluation of 27 individual data sets from 2MASS, CFHTLS and SDSS, as well as several archival data sets. In addition we augmented the photometry of 31 objects by literature values, such as *GALEX* PanSTARRS and *WISE* data. Owing to *GALEX*'s and *WISE*'s large point-spread functions, we only included their photometry if a contamination by neighbouring objects can be excluded. Among the 16 objects whose photometry is entirely based on literature results, four galaxies are in the footprint of the COSMOS survey: PS1-12zn, PS1-12bqf, SN1000+0213 and SNLS07D2bv. Their photometry is discussed here for the first time. Table A1 summarises the photometry of each object.

3.3 Spectral-energy distribution fitting

We modelled the SEDs with *Le Phare* (Arnouts et al. 1999; Ilbert et al. 2006),¹⁰ using a grid of galaxy templates based on Bruzual & Charlot (2003) stellar population-synthesis models with a Chabrier IMF (Chabrier 2003), a star-formation history approximated by a declining exponential function of the form $\exp(t/\tau)$, where t is the age of the stellar population and τ the e-folding time-scale of the star-formation history (varied in eight steps between 0.1 and 15 Gyr), and a Calzetti dust attenuation curve (Calzetti et al. 2000). For a description of the galaxy templates, physical parameters of the galaxy fitting, and their error estimation, we refer to Krühler et al. (2011).¹¹

As an extension to Krühler et al. (2011), we relaxed the analysis threshold of the galaxy mass to $10^4 M_\odot$ (which is pushing the definition of a galaxy), because previous studies have shown that SLSNe can occur in very low-mass galaxies (Lunnan et al. 2014; Leloudas et al. 2015c; Angus et al. 2016). We furthermore incorporated the empirical line strength to star-formation-rate conversion for [O II] and [O III] presented in Krühler et al. (2015) and reddened the emission lines by $E(B - V)_{\text{star}} = 0.44 \times E(B - V)_{\text{gas}}$ (Calzetti et al. 2000). Finally, we use the high-resolution BC03 templates which are defined over 6900 instead of 1221 wavelength points from 9.1×10^{-3} to $160 \mu\text{m}$. To account for zeropoint offsets in the cross calibration and absolute flux scale, we added a systematic error of 0.05 mag in quadrature to the uncertainty introduced by photon noise. For *GALEX* UVOT and *K*-band data this systematic error was increased to 0.1 mag.

The absolute magnitudes were computed directly by convolving the filter response functions with the best-fit template. To compute the corresponding error $\sigma(M_Q)$ in the rest-frame bandpass Q , we interpolate between the errors of the apparent magnitudes $\sigma(m_k)$ and $\sigma(m_l)$ of the observed band-pass k and l , respectively, via:

$$\sigma(M_Q) = \frac{\sigma(m_k) - \sigma(m_l)}{\lambda_{\text{rest},k} - \lambda_{\text{rest},l}} (\lambda_{\text{rest},Q} - \lambda_{\text{rest},l}) + \sigma(m_l)$$

¹⁰ <http://www.cfht.hawaii.edu/~arnouts/LEPHARE>

¹¹ The templates used in this paper do not account for possible binary star evolution, which could substantially alter SEDs (more hard UV photons; e.g., Stanway et al. 2016).

where $\lambda_{\text{rest},k/l} = \lambda_{\text{obs},k/l}/(1+z)$ is the central wavelength of the observer-frame bandpass k and l in the rest-frame of the SLSN. In case a rest-frame bandpass lies blueward/redward of the observation in the bluest/reddest filter, we set the error $\sigma(M_Q)$ to the error of the observation in the bluest/reddest filter.

Our observations were characterised by a large set of different filters, of which several have similar bandpasses. To simplify the fitting, we homogenised the filter set. Specifically, we set the filter response function of *F336W*, *u*_{PS1}, *u*^{*}, *uvu* to *u'*, *F475*, *g*_{DES}, *g*_{High}, *g*_{PS1}, *g* to *g'*, *r*_{DES}, *r*_{PS1}, *r* to *r'*, *F775W*, *i*_{DES}, *i*_{PS1}, *i* to *i'*, *F850LP*, *z*_{DES}, *z*_{Gunn}, *z*_{PS1}, *z*⁺ to *z'*, *F390W* *U38* to *U*, *Bj* to *B*, *Vj* to *V*, *I_c*, *F814W* to *I*, *y*_{PS1} to *Y*, *F160W* to *H*, *W1* to *Spitzer*/3.6 μm and *W2* to *Spitzer*/4.5 μm . It can be seen from our fits (Figs. 2, B1 and B2), and quality of the derived host properties (Table 4), that the impact of these assumptions is negligible.

Studies of SLSN host galaxies and extreme emission-line galaxies (e.g., Amorín et al. 2015) have shown that emission lines can significantly affect the SED fitting. To quantify this effect, we repeated the SED fitting for our spectroscopic sample (Leloudas et al. 2015c; Table 1). The contribution of the emission line i on the photometry in filter j is given by

$$\begin{aligned} \Delta m_{i,j} &= -2.5 \log \left(\frac{f_{\lambda,c}(\lambda) + f_{\lambda,i}^i(\lambda)}{f_{\lambda,c}(\lambda)} \right) \\ &= -2.5 \log \left(1 + \frac{\int d\lambda f_{\lambda,i}^i(\lambda) T_j(\lambda)}{\int d\lambda f_{\lambda,c}(\lambda) T_j(\lambda)} \right) \end{aligned}$$

where $f_{\lambda,i}^i$ is the flux density of the emission line i , $f_{\lambda,c}$ is the flux density of the stellar continuum and $T_j(\lambda)$ is the transmission function of the filter j . The strength of an emission line can be characterised by its equivalent width, EW, hence $f_{\lambda,i}^i = f_{\lambda,c} \times \text{EW}_i$. Assuming that the emission line is narrow compared to the width of the broad-band filter, the above expression simplifies to

$$\Delta m_{i,j} = -2.5 \times \log \left(1 + \frac{\text{EW}_i T_j(\lambda_i)}{\Delta \lambda_{j,\text{eff}}} \right)$$

where $T_j(\lambda_i)$ is the filter response function of filter j at the wavelength of the emission line i (in the air reference frame) and $\Delta \lambda_{j,\text{eff}}$ is the effective width of the filter. In contrast to the SED fitting, it is necessary to use the exact filter transmission function of each instrument.

We subtracted the contribution of H α –H δ , [O II], [O III], [N II], [Ne II] and [S II] from the measured brightness in the broadband filter. Afterwards, we explicitly switched off the contribution from the ionised gas of H II regions in *Le Phare* and repeated the fits with the emission-line-subtracted SEDs. The result of this experiment is discussed in Sect. 4.1.2.

3.4 Ensemble statistics

To extract robust estimates of the ensemble distribution functions, we used a Bayesian approach which comprises of MonteCarlo (MC) simulation to propagate measurement errors and bootstrapping with the resampling package *MultiNest* (Feroz et al. 2013) through its python binding *PyMultiNest* (Buchner et al. 2014) to propagate sampling

Table 2. Properties of the comparison samples and their selection criteria

Sample	Selection criteria	Number of objects	Redshift interval	Which properties used?
Core-collapse supernova host galaxies (total number 265)				
Leloudas et al. (2011) (L11)	Ib/c SNe, detected by untargeted surveys spectroscopic classification	12	$0.02 \leq z \leq 0.18$ $\bar{z} = 0.04$	M_B , mass, SFR ¹
Sanders et al. (2012) (S12)	Ib/c SNe, detected by untargeted surveys spectroscopic classification	31	$0.01 \leq z \leq 0.26$ $\bar{z} = 0.03$	M_B , mass, SFR ¹
Svensson et al. (2010)	GOODS SN sample photometric SN classification	165	$0.28 \leq z \leq 1.30$ $\bar{z} = 0.47$	M_B , mass, SFR
Stoll et al. (2013) (S13)	first-year PTF CCSN sample primarily Type IIp/L SNe	58	$0.01 \leq z \leq 0.18$ $\bar{z} = 0.04$	M_B , mass, SFR
Extreme emission-line galaxies (total number 227)				
Atek et al. (2011)	WISPS survey (Atek et al. 2010), $0.5 < z < 2.3$ $EW_{\text{rest}}([\text{OIII}]\lambda 5007) > 200 \text{ \AA}$	9	$0.9 \leq z \leq 2.04$ $\bar{z} = 1.36$	mass, SFR
Amorín et al. (2014)	VUDS survey (Le Fèvre et al. 2015), $23 \text{ mag} < I(\text{AB}) < 25 \text{ mag}$	31	$0.21 \leq z \leq 0.86$ $\bar{z} = 0.57$	colour, m_R , M_B , mass, SFR
Maseda et al. (2014)	3D-HST survey (Brammer et al. 2012), colour selection emission-lines do not fall in the NIR band-gaps	22	$1.3 \leq z \leq 2.3$ $\bar{z} = 1.65$	mass, SFR
Amorín et al. (2015)	zCOSMOS survey, $I(\text{AB}) \leq 22.5 \text{ mag}$ $EW_{\text{rest}}([\text{OIII}]\lambda 5007) > 100 \text{ \AA}$	165	$0.11 < z < 0.92$ $\bar{z} = 0.48$	colour, m_R , M_B , mass, SFR
Field galaxies (total number 150 900)				
Muzzin et al. (2013)	K-band selected COSMOS/UltraVISTA survey $SFR > 10^{-3} M_{\odot} \text{ yr}^{-1}$, $USE = 1$, $z < 4$ $10^{-13} \text{ yr}^{-1} < sSFR < 10^{-7.5} \text{ yr}^{-1}$	150 900	$0.01 \leq z \leq 3.96$ $\bar{z} = 0.97$	colour, m_R , mass, SFR
Long GRB host galaxies (total number 52)				
Krühler (priv. comm.)	$z < 1$, long-duration <i>Swift</i> GRBs detected before May 2014, part of the GROND 4-hour, TOUGH, SHOALS BAT-6 samples	52	$0.06 \leq z \leq 0.98$ $\bar{z} = 0.67$	colour, m_R , M_B , mass, SFR

Note. — The selection criteria comprise of the ones of each survey and the ones we imposed to build the final samples. All samples were cleaned from duplicates. ¹ We use the re-computed values in [Leloudas et al. \(2015c\)](#).

errors. In the MC simulation each measurement was represented by an asymmetric normal distribution, to include asymmetric errors, and, in the case for a non-detection, a uniform distribution where the lower bound was set to the faintest/lowest measurement. After resampling each observation 30 000 times, we bootstrapped the samples with *PyMultiNest*. The properties of the posterior distribution were extracted by fitting the distributions with normal distributions.

To compare observed distributions with different parent distributions, such as extreme emission-line galaxies (hereafter EELGs), GRBs and SNe, we performed a MC simulation as follows. Each measurement was represented by a normal distribution centred at the observed value and with a width (1σ) determined from the asymmetric error or a uniform distribution between the upper limit and the smallest/faintest value in the sample for those objects with upper limits only. A two-sided Anderson-Darling (AD) test was performed between the resampled and the parent distribution, using the R package *kSamples*. This process was repeated 10000 times and a mean AD value obtained. We reject the null hypothesis of two distributions being drawn from the same parent distribution if the corresponding p_{ch} -value was smaller than 0.01. In addition to the error propagation, we also performed a two-sided AD test on their red-

shift distributions to minimise systematic errors introduced by cosmic evolution, similar to [Japelj et al. \(2016\)](#).

3.5 Comparison samples

We built several comparison samples to put SLSN host galaxies in context with the cosmic star-formation history and to better understand the peculiar conditions that gave rise to this class of stellar explosion.

Core-collapse supernova host galaxies: Because of the connection between SLSNe and massive stars, we compiled core-collapse supernova (CCSN) host galaxy samples. As in [Leloudas et al. \(2015c\)](#), we used SNe from untargeted (with respect to galaxies) surveys. At $z < 0.3$, we use objects studied in [Leloudas et al. \(2011\)](#), [Sanders et al. \(2012\)](#) and [Stoll et al. \(2013\)](#). All SNe in these samples have robust spectroscopic classifications. The combined sample consists of 44 type Ib/c SNe and 46 type II SNe. These studies provide multi-band data, which is primarily based on SDSS photometry and also spectroscopy for a number of hosts. We adopt the SED modelling by [Leloudas et al. \(2015c\)](#) for the [Leloudas et al. \(2011\)](#) and [Sanders et al. \(2012\)](#) samples. Note, the spectral energy distributions in [Stoll et al. \(2013\)](#) were modelled with the FAST stellar population synthesis

code (Kriek et al. 2009) with the Bruzual & Charlot (2003) templates and a Salpeter IMF. We reduced their SFRs by a factor of 1.7, to convert from a Salpeter to a Chabrier IMF, used in this paper (Kennicutt 1998).

To expand the SN sample to redshifts larger than $z > 0.3$, where most of our SLSNe are found, we added the SN sample from the Great Observatories Origins Deep Survey (GOODS) and Probing Acceleration Now with Supernovae (PANS) surveys (Riess et al. 2004). GOODS/PANS was an *HST* survey to detect Type Ia SNe at high redshift. This survey also located 58 distant CCSNe between $z = 0.28$ and $z = 1.3$ (the median being $\bar{z} = 0.47$). In contrast to the low- z samples, the classification relied on photometric data. The method allowed a distinction between Type Ia and CC-SNe, but not into sub-types. Thanks to the overlap with the GOODS field, each SN host has deep rest-frame UV to NIR data. We adopt the results of the SED modelling by Svensson et al. (2010). Note, these authors modelled the SEDs with their own software that uses observed SEDs of local galaxies and SEDs produced with various spectral synthesis codes as templates. Furthermore, they assumed a Salpeter IMF. Similar to Stoll et al. (2013), the SFRs were reduced by a factor of 1.7 to convert from a Salpeter to a Chabrier IMF.

GRB host galaxies: A member of our team (T. Krühler) collected multi-band data of long GRBs. These GRBs are selected to be part of one of the following complete GRB samples: GROND 4-hour sample (Greiner et al. 2011), TOUGH survey (The Optically Unbiased GRB Host Galaxy survey; Hjorth et al. 2012), BAT-6 (Salvaterra et al. 2012) and SHOALS (*Swift* Gamma-Ray Burst Host Galaxy Legacy Survey; Perley et al. 2016b). Among all hosts, we selected those at $z < 1$ (52 in total). At these redshifts, it is relatively easy to secure the GRB redshift, because of the sparsity of dust-obscured bursts at $z < 1$, and to build host samples with a high detection completeness. The SEDs of this sample were analysed in a similar way as our SLSN host galaxy sample.

COSMOS/UltraVISTA survey: To compare SLSN host galaxies to field galaxies, we use the ultra-deep NIR survey UltraVISTA that observed an area of 1.8 deg^2 down to $K_s = 23.9 \text{ mag}$ (5σ confidence). We chose the K -band, i.e., mass, selected catalogue by Muzzin et al. (2013) that overlaps with the COSMOS field. This catalogue provides observations in 30 bands from rest-frame UV to NIR. Among all galaxies, we selected those at $z < 4$ with SFRs of at least $10^{-3} M_\odot \text{ yr}^{-1}$, specific SFRs between 10^{-13} yr^{-1} and $10^{-7.5} \text{ yr}^{-1}$, and “USE” flags equal to one. This sample comprises $\sim 151\,000$ galaxies with a median redshift of $\bar{z} = 0.97$. Because of the small survey area, the number of hosts at $z < 0.1$ is small. This does not affect our analysis because only two SLSNe in our sample are at lower redshifts.

EELGs: Leloudas et al. (2015c) showed that H-poor SLSNe are preferentially found in EELGs. We built a master sample including results from Atek et al. (2011), Amorín et al. (2014, 2015) and Maseda et al. (2014). Those samples selected EELGs by applying different brightness cuts, colour selection criteria, spectroscopy and redshift constraints. The total sample consists of 227 galaxies with rest-frame [O

III] $\lambda 5007$ equivalent widths of $> 100 \text{ \AA}$ between $z = 0.11$ and $z = 2.3$. All surveys reported stellar mass and SFR for each galaxy, but other properties, such as brightness, colour or M_B , are only reported for certain subsamples.

A summary of the individual surveys and which properties are used in this study is presented in Table 2.

4 RESULTS

4.1 Spectral-energy distribution modelling

4.1.1 Quality of the SED modelling

We made two assumptions to model all SEDs in an automatic and self-consistent way: *i*) a galaxy SED can be approximated by a single-age stellar population and the ionised gas of the H II regions and *ii*) the number of filters (n.o.f.) can be reduced to the homogenised filter list in Sect. 3.3. Over 90% of our hosts have good fits with an average $\chi^2/\text{n.o.f.}$ of 0.5 and derived physical parameters that are comparable to other galaxy samples (Table 4, Figs. 2, B1, B2).

The fits of only six hosts had $\chi^2/\text{n.o.f.}$ between 3.9 and 10.4. The fits of PS1-11bdn and SN1000+0216 are of poorer quality ($\chi^2/\text{n.o.f.} = 3.9$ and 6.3, respectively) due to a few data points. The host of PS1-10bjz has very strong emission lines that fall in the wings of the i' -band transmission function, which increased the normalised $\chi^2/\text{n.o.f.}$ to 10.4. Apart from data points in a few individual filters, the fits are nonetheless very good and can be used without restriction.

The fits of CSS100217, PTF11dsf, SN1999bd and SN2006gy have to be used with more caution. Drake et al. (2011a) revealed a narrow-line Seyfert in the host galaxy of CSS100217, and ? a broad-component under the H α and [O III] emission lines, which could be due to an AGN. The hosts of the SLSNe-II in SN1999bd and SN2006gy are evolved galaxies that experienced a recent starburst. This is demonstrated by the detection of Balmer lines in both spectra (Smith et al. 2007; Leloudas et al. 2015c; Fox et al. 2015), while the SED cannot be modelled by a single-age stellar population. A reliable modelling of the SEDs of these three hosts requires a full consideration of their star-formation histories (SNe 1999bd and 2006gy) and the inclusion of an AGN component (CSS100217), which is beyond the scope of this paper. Leloudas et al. (2015c) mentioned that the host of PTF11dsf could also harbour an AGN. Like for the three aforementioned hosts, we only use the mass and the B -band luminosities of PTF11dsf’s host but not the SFR in our discussion.

4.1.2 Contribution of emission lines

Our SED modelling includes the contribution of the H II regions in the SED modelling. This is of particular importance because previous studies showed that emission lines can significantly affect the SED fitting (e.g. Castellano et al. 2014; Lunnan et al. 2014; Chen et al. 2015; Santini et al. 2015). This motivated Lunnan et al. (2014) to omit filters that were affected by [O III] $\lambda 5007$, if [O III] had a large equivalent width, and Chen et al. (2015) to subtract the emission line contribution from the broad-band photometry. Both

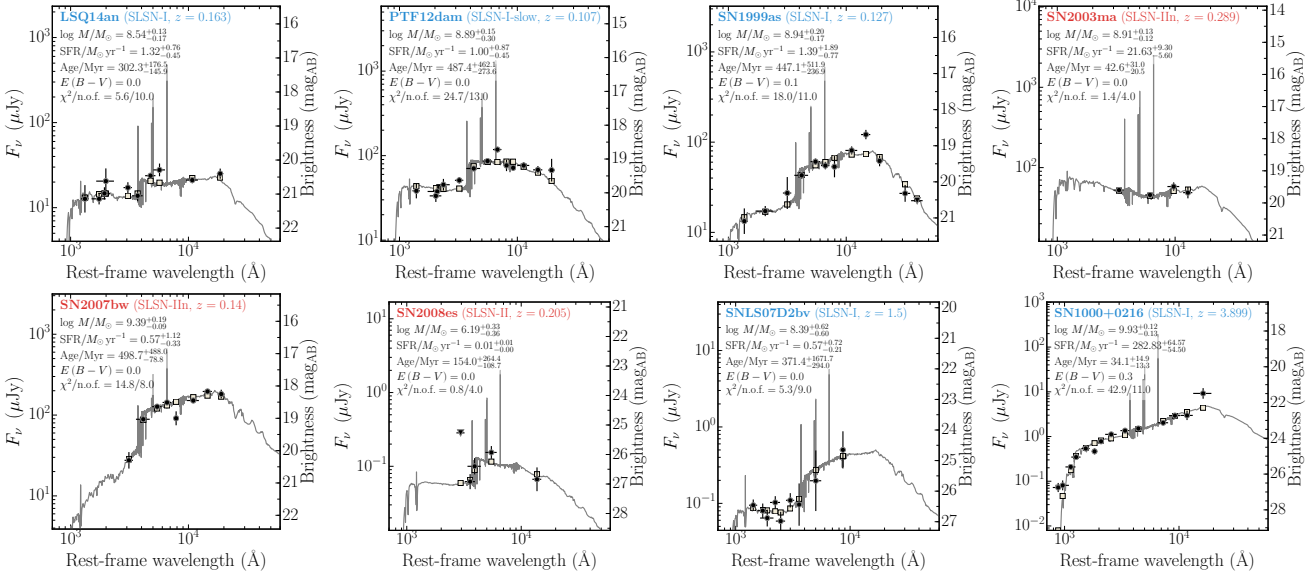


Figure 2. Selection of spectral energy distributions of hosts of H-poor and -rich SLSNe from 1000 to 40000 Å. The solid line displays the best-fit model of the SED with *Le Phare*. The squares in a lighter shade are the model predicted magnitudes. The fitting parameters are displayed for each SED. See Table 4 and Sect. 3.3 for details. The full collection of SEDs are shown in Figs. B1 and B2.

approaches are strictly limited to objects with host spectroscopy.

Thanks to *Le Phare* capabilities, we quantified the impact of emission-lines on the SED fitting with a more sophisticated approach. First, we fit the SEDs of the spectroscopic subsample with templates that included a stellar and a gas component. Then we subtracted the contribution of the emission lines from the broad-band photometry and fit the new SEDs only with a stellar component, i.e., the gas component is explicitly switched off in *Le Phare*.

Figure 3 shows how the primary diagnostics mass and SFR change if emission lines are included in the SED fitting. The average random error in the mass and SFR estimates is ~ 0.15 dex. The most critical object in this analysis is PTF12dam, the most extreme SLSN host galaxy known to date. Its deviations between the mass and SFR estimates with and without lines are $\Delta\text{SFR} = \log \text{SFR}_{\text{w/lines}} - \log \text{SFR}_{\text{w/o lines}} = -0.47 \pm 0.45$ dex, $\Delta M = 0.48 \pm 0.42$ dex. The excellent agreement between the fits reflects that we have good photometry spanning a large wavelength interval and a good handle on the gas emission in the SED fitting, so that the uncertainty in the emission-line contribution does not affect our results.

4.1.3 SED vs. emission-line diagnostics

A sub-sample of 16 host galaxies in our spectroscopic subsample have a reliable absolute flux calibration, allowing us a direct comparison of the SED and emission-line derived attenuation and SFR measurements.

The left panel of Fig. 4 compares the extinction-corrected SFR's from SED modelling and H α emission lines. Both diagnostics reassuringly show consistency. The observed r.m.s. of 0.52 dex (a factor of 3.3) is in the expected uncertainty range. Both diagnostics depend on *i*) the star-burst being roughly constant over some fixed time interval,

ii) the shape of the IMF and *iii*) a robust extinction correction.

The former two items are critical for extreme galaxies such as SLSN host galaxies. For instance, if the star-formation activity is very young, e.g., 3 Myr for PTF12dam (Thöne et al. 2015), the normalisation constant of the UV SFR estimator will be underestimated by a factor of a few, while the normalisation constant would only vary by a few percent if the star-formation activity lasts longer than 100 Myr (Calzetti 2013). In addition to the aforementioned issues, emission-line inferred SFRs are subject to slit-loss corrections and SED-based SFRs are degenerate between age, dust and metallicity. Conroy (2013) pointed out that the systematic uncertainty in the SED-based SFRs is likely a factor of ~ 2 (0.3 dex), which is comparable but smaller than the observed r.m.s. of 0.52 dex.

The attenuation measurements displayed in the right panel of Fig. 4 are consistent with each other. This is a very important cross-check because the attenuation in the SED is measured from the stellar component while the attenuation inferred from the Balmer decrement is sensitive to dust. These diagnostics are known to differ by a factor of two (Calzetti et al. 1994), which we took care of in the SED modelling (Sect. 3.3). A few hosts show larger deviations or even evidence of negative dust attenuations. In most cases the significance is smaller than 3.5 σ .

The good consistency between the different methods shows that we can extract reliable results with *Le Phare* also for the galaxies where spectroscopic information is not available.

4.2 Host offsets

Figures 5, C1 and C2 show postage stamps of each field in our sample. Marked by the green circles are the detected host galaxies (detection rate of $\approx 90\%$). Highlighted by the

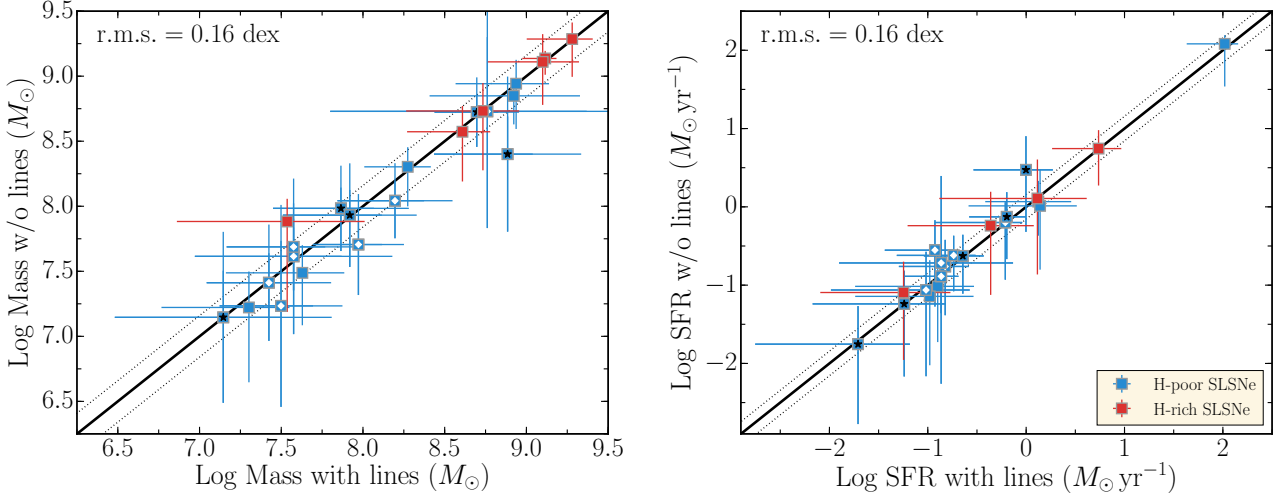


Figure 3. Derived masses (left) and SFRs (right) of galaxies from the spectroscopic sub-sample. The SEDs are fitted with two different procedures: *i*) the photometry of the galaxies with the contribution of the emission lines is fit with galaxy templates and an emission line component in **Le Phare**; *ii*) the photometry of the same galaxies is fit after removal of the emission line contribution and switching off the ionised gas component in **Le Phare**. The value in the upper left corner reports the average r.m.s. between the measurements with and without emission-line contribution. The solid line indicates the 1:1 correlation and the dotted lines are shifted by $1 \times \text{r.m.s.}$. The agreement is very good, showing that we can obtain reliable results with **Le Phare** also for the galaxies where spectroscopic information is not available. The hosts of fast and slow-declining H-poor SLSNe are signified by ‘★’ and ‘◇’, respectively, and SLSNe-II by ‘+’.

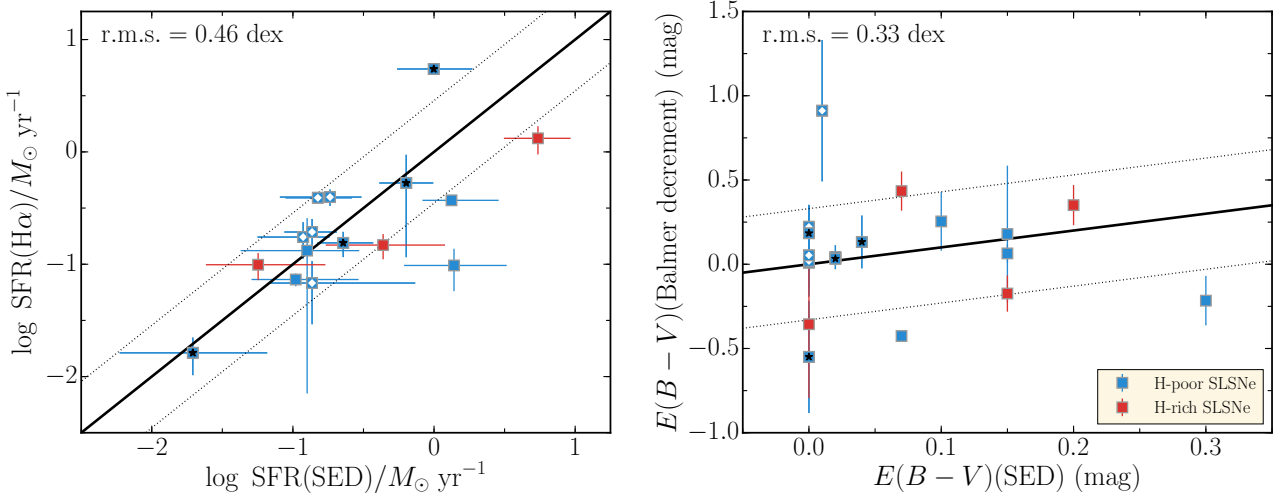


Figure 4. SFR (left) and attenuation (right) obtained from SED modelling and from emission lines for the spectroscopic sub-sample. The value in the upper left corner reports the average r.m.s. between the different diagnostics. The solid line indicates the 1:1 correlation and the dotted lines are shifted by $1 \times \text{r.m.s.}$. Symbols are identical to Fig. 3.

crosshair are the SN positions after astrometrically aligning the SN and host images. The average uncertainty of $0''.17$ is dominated by the different pixel scales of the SN and host images. In a few examples, this uncertainty exceeds $1''$ because of the coarse spatial resolution of the SN images, the small spatial overlap of SN and host images, or the low number of reference stars. For 17 hosts in our sample we lack SN images. Their SN positions are indicated by circles as reported in the literature.

Thanks to the high host recovery rate (85% and 100% for H-poor and -rich SLSNe, respectively), we present a relatively complete host offset distribution of H-poor and H-rich SLSNe. In addition, we incorporated results on CSS100217

by Drake et al. (2011a), on SN2003ma by Rest et al. (2011) and on Pan-Starrs SLSNe by Lunnan et al. (2015). The observed distribution is skewed to small radii (the expectation value being 1.3 kpc) but has a long tail extending up to 12 kpc. For the smallest offsets, the measurements are comparable to the errors. In this regime, Gaussian noise superimposed on a vector with length μ results in a non-Gaussian probability distribution of the vector length, i.e., an overestimated host offset (Rice 1944). The expected probability distribution function of a host offset measurement r is given by

$$p(r|\mu, \sigma) = \frac{r}{\sigma^2} I_0\left(\frac{r\mu}{\sigma^2}\right) \exp\left(-\frac{r^2 + \mu^2}{\sigma^2}\right) \quad (1)$$

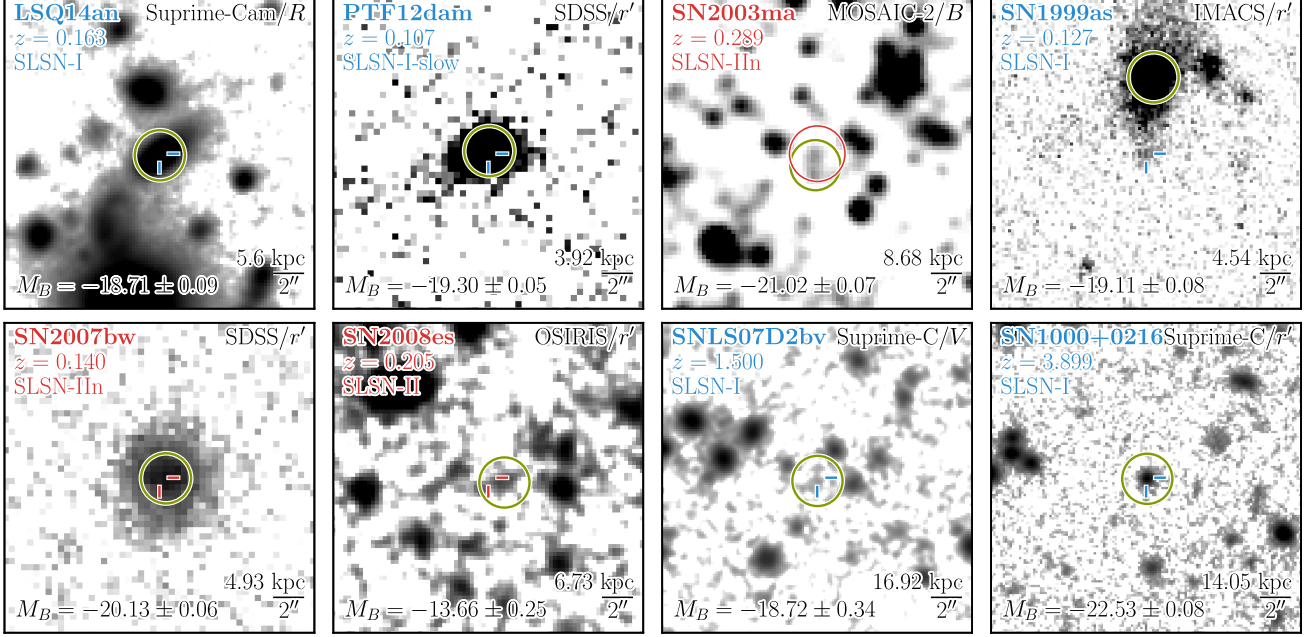


Figure 5. Selection of postage stamps of the H-poor and -rich SLSNe in our sample. Each panel has a size of $20'' \times 20''$ where North is up and East is left. The crosshair marks the position of the SNe after aligning a SN and a host image. If no SN image was available, the blue circle (arbitrary radius) indicates the SN position reported in the literature. The average alignment error was $0''.17$ but it exceeded $1''$ in a few cases. The green circle (arbitrary radius) marks the host galaxy. The observed absolute B -band brightness is displayed in the lower left. The image of SNLS07D2bv was smoothed with a Gaussian kernel (width of 1 px) to improve the visibility of the field. The complete collection of postage stamps are shown in Figs. C1 and C2.

where μ is the true offset, σ is the dispersion of the distribution, which can be assumed to be comparable to the measurement error, and I_0 is the modified Bessel function of the first kind. By differentiating $p(r|\mu, \sigma)$ with respect to r , a closure relation between the observed offset, its error and the true offset can be derived (Wardle & Kronberg 1974):

$$I_0\left(\frac{r\mu}{\sigma^2}\right)\left(1 - \frac{r^2}{\sigma^2}\right) + \frac{r\mu}{\sigma^2} I_1\left(\frac{r\mu}{\sigma^2}\right) = 0. \quad (2)$$

We solved this equation numerically to build the intrinsic host offset distribution. The black curve in Fig. 6 shows the joint cumulative distribution of H-poor and -rich SLSNe. The grey-shaded regions displays the expected parameter space of our distribution after bootstrapping the sample 30 000 times with darker regions indicating a higher probability. The distribution is well described by the cumulative distribution function of a negative exponential distribution $1 - \exp(-r/r_{\text{mean}})$ with a mean offset of $r_{\text{mean}} \sim 1.3$ kpc.

The fit underpredicts the fraction of hosts with offsets smaller than < 0.5 kpc and > 4 kpc. The discrepancy for low host offsets can be reconciled with the alignment error between SN and host images and intrinsically small host offsets. As the alignment error exceeds the offset measurement, the closure relation is only fulfilled if $\mu \rightarrow 0$. Therefore, the fraction of SLSNe with negligible host offsets is a strict upper limit. The blue and red curve in Fig. 6 shows the offset distribution after separating the sample in H-poor and -rich SLSNe, respectively. Both samples are statistically identical.

Remarkable are the large offsets of PTF11rks and SN1999as with > 10 kpc in contrast to the distribution me-

dian of 0.7 kpc. The host of SN1999as is an irregular galaxy interacting with its environment (Fig. 5). At the explosion site a faint object is detected in continuum. The explosion site of PTF11rks is connected by a linear feature with the nucleus (Perley et al. 2016b). This could point to a spiral galaxy morphology or galaxy interaction whereby the SN exploded in a faint satellite galaxy. Spectroscopic observation of SN1999as by Leloudas et al. (2015c) showed that the explosion site is characterised by strong emission lines. In this case, the true host is a fainter galaxy that is difficult to disentangle from the more massive galaxy.

4.3 Brightness, colour and luminosity

4.3.1 Brightness and luminosity

More than 87% of all hosts were detected at $> 2\sigma$ confidence in a R -band filter. Their observed distribution, displayed in the upper panel of Fig. 7, extends from $R \sim 13.3$ mag (SN2006gy) to $R \sim 27.9$ mag (SCP06F6) and shows a clear trend to fainter galaxies as redshift increases (Table 3). The average brightness of SLSN-I host galaxies decreases from $m_R \sim 22.7$ mag at $z \sim 0.5$ to $m_R \sim 25.4$ mag at $z > 1$, while the dispersion remains at ~ 1.6 mag at all redshifts. Compared to a sample of star-forming galaxies from the UltraVISTA survey (density plot in Fig. 7), they are on average fainter and their distributions become more incompatible as redshift increases (Fig. D2).

The class of H-poor SLSNe is comprised of fast- and slow-declining SLSNe, which might have different progenitors and host environments. Using the gap in the decline

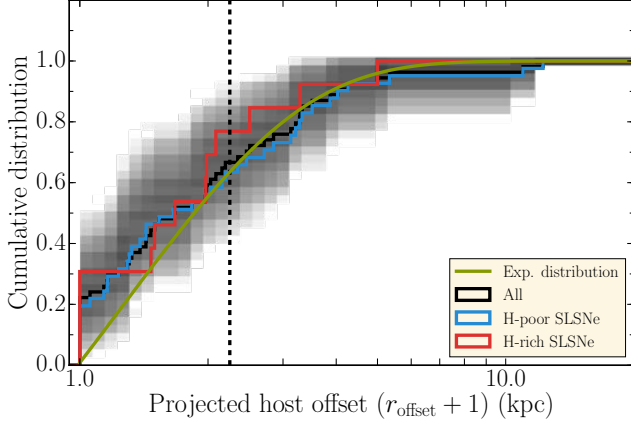


Figure 6. Host offset cumulative distribution for H-poor (41; blue) and -rich SLSNe (13; red) and the total sample (black). The shaded region displays the expected parameter space after bootstrapping the sample 30000 times.

time scale at ~ 50 days (Table 1), we define a sub-sample of 12 fast and seven slow declining H-poor SLSNe at $z < 0.5$ (Table 1). The properties of the two samples appear to be indistinguishable (Fig. D2; Table 3). However, the samples are too small to draw a strong conclusion yet.

Host galaxies of H-rich SLSNe are on average 1.5 mag brighter than hosts of H-poor SLSNe at $z < 0.5$ (upper panel in Fig. 7; Table 3). Most striking about the SLSN-II/IIn host population is the exceptionally large dispersion of 3.4 mag that is even a factor of three larger than that of H-poor SLSNe as well as the UltraVISTA sample (Tables 3, D1; Fig. D1). The dispersion remains even after separating out the three SLSNe-II from the H-rich population (Table 1). The distribution is incompatible with the UltraVISTA sample ($p_{\text{ch}} = 7 \times 10^{-4}$) and with the fainter and narrower distribution of SLSN-I host galaxies ($p_{\text{ch}} = 8.4 \times 10^{-3}$). Among the hosts of the three SLSNe-II are two of the faintest H-rich SLSN host galaxies in our sample ($R \sim 24.6$ –26.4; Table A1). They are more than a hundred times fainter than a $L_{\star,B}$ galaxy at $z \sim 0.2$ (Faber et al. 2007), and about 2 mag fainter than the SMC-like galaxy at $z \sim 0.2$.

Panel A of Figure 8 shows the evolution of the rest-frame B -band luminosity (not corrected for host reddening). The distribution spans a wide range from -13 to -22 mag. Compared with appropriate luminosity functions (e.g., Faber et al. 2007; Ilbert et al. 2005; Marchesini et al. 2007, tracks in Fig. 8), the span corresponds to a range from a few thousandths of L^* to a few L^* . Clear differences are visible between hosts of H-poor and -rich SLSNe. In their common redshift interval ($z < 0.5$), the distribution of the H-poor SLSN hosts is narrower by > 1 mag and in addition shifted by ~ 1 mag towards lower luminosities (Table 3). Intriguingly, the luminosity distribution shows a rapid evolution from $0.04 L^*$ at $z < 1$ to $\sim 0.2 L^*$ at $z > 1$. We discuss its origin in Sect. 5.1.

With the B -band luminosity distribution in hand we put SLSN host galaxies into context with unbiased GRB and ordinary core-collapse SN host galaxy samples. Between $z = 0.3$ and $z = 1$, Type I SLSNe reside in galaxies that are 1.61 ± 0.42 mag less luminous than GRBs (Tables 3, D1). The AD test gives a chance probability of $p_{\text{ch}} = 2 \times 10^{-4}$ (Fig.

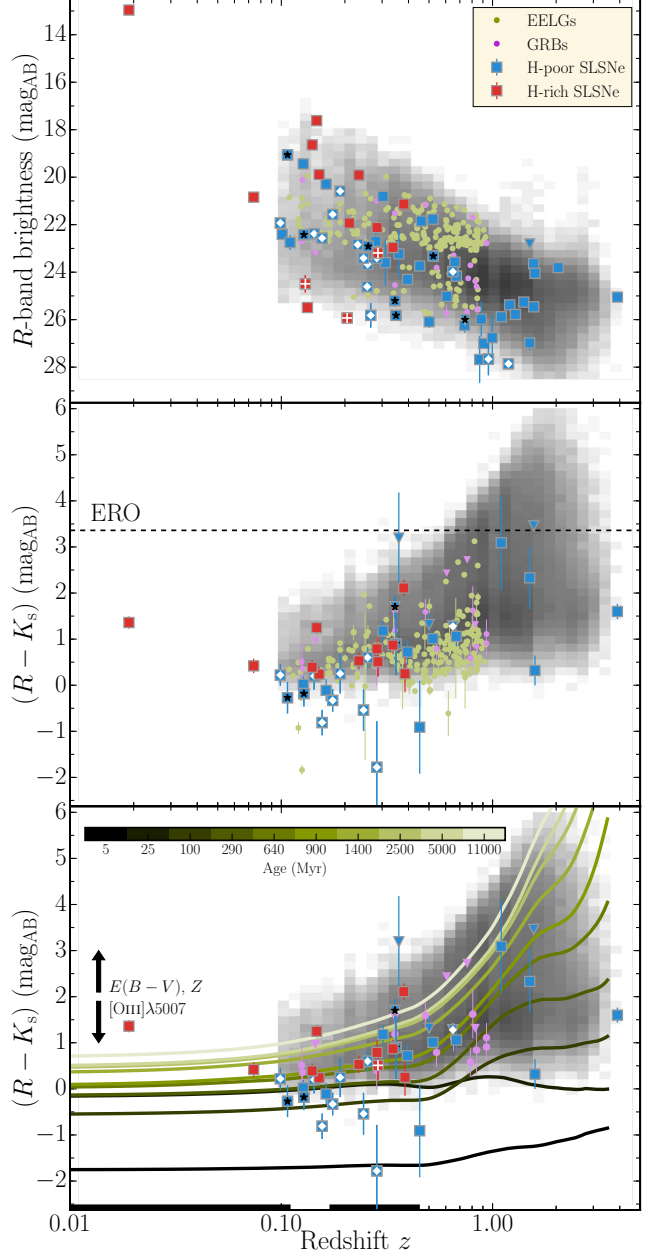


Figure 7. *Top:* The observed R -band host magnitude as a function of redshift for H-poor (blue) and H-rich (red) SLSNe. Upper limits are indicated by downward pointing triangles. The hosts of fast and slow-declining H-poor SLSNe are signified by ‘ \star ’ and ‘ \diamond ’, respectively, and SLSNe-II by ‘+’. *Middle:* The $R - K_s$ colour evolution. In general the colour is significantly bluer than of typical star-forming galaxies. *Bottom:* The observed $R - K_s$ colour evolution of SUSHIES and GRB host galaxies and star-forming galaxies from the UltraVISTA survey (density plot). Overlaid are the colour evolution from Bruzual & Charlot (2003) templates with $Z = 1/5 Z_{\odot}$ for different stellar population ages. The tracks are shown up to $z = 3.5$ to avoid corrections for Ly α absorption in the host galaxies and in the intergalactic medium. The vectors on the left indicate how extinction, metallicity and emission-lines with very large equivalent widths, such as H α and [O III] $\lambda 5007$, alter the colour. Note, H α and [O III] $\lambda 5007$ can turn the colour to the blue only at $z \lesssim 0.11$ and between $z \sim 0.17$ and $z \sim 0.45$, respectively (indicated by the bars at the bottom).

Table 3. Statistical properties of H-poor and -rich SLSN host galaxies per redshift bin

Sample	Number	Mean redshift	$m_R^{(a)}$ (mag)	$(R - K_s)^{(a)}$ (mag)	M_B (mag)	$\log M/M_\odot$	$\log \text{SFR}$ ($M_\odot \text{ yr}^{-1}$)	$\log \text{sSFR}$ (yr^{-1})
$z \leq 0.5$								
I-fast	11	0.21	22.96 ± 0.48 $1.46^{+0.42}_{-0.33}$	-0.10 ± 0.24 (8) $0.41^{+0.37}_{-0.19}$	-16.71 ± 0.37 $1.14^{+0.31}_{-0.24}$	7.86 ± 0.16 $0.45^{+0.14}_{-0.11}$	-0.89 ± 0.08 $0.03^{+0.05}_{-0.02}$	-8.70 ± 0.11 $0.05^{+0.11}_{-0.04}$
I-slow	5	0.24	23.06 ± 1.58 $3.00^{+1.43}_{-0.97}$	0.01 ± 0.26 (4) $0.07^{+0.20}_{-0.05}$	-16.76 ± 0.96 $1.82^{+0.80}_{-0.50}$	7.69 ± 0.49 $0.86^{+0.49}_{-0.31}$	-0.73 ± 0.29 $0.22^{+0.63}_{-0.16}$	-8.55 ± 0.33 $0.15^{+0.52}_{-0.12}$
H-poor	27	0.24	22.68 ± 0.34 $1.75^{+0.27}_{-0.24}$	0.07 ± 0.16 (16) $0.50^{+0.16}_{-0.12}$	-17.10 ± 0.30 $1.45^{+0.23}_{-0.20}$	7.94 ± 0.13 $0.62^{+0.12}_{-0.10}$	-0.61 ± 0.11 $0.40^{+0.13}_{-0.10}$	-8.59 ± 0.10 $0.10^{+0.24}_{-0.07}$
II	3	0.21	24.46 ± 1.46 $1.77^{+1.47}_{-0.80}$	\dots \dots	-15.29 ± 1.48 $2.31^{+1.50}_{-0.90}$	7.22 ± 0.93 $1.18^{+0.93}_{-0.52}$	-1.27 ± 0.72 $0.80^{+1.01}_{-0.45}$	-8.39 ± 0.42 $0.08^{+0.26}_{-0.06}$
IIIn ^(b)	13	0.21	20.37 ± 0.96 (12) $3.25^{+0.82}_{-0.65}$	0.83 ± 0.22 (10) $0.60^{+0.19}_{-0.14}$	-18.89 ± 0.67 $2.30^{+0.56}_{-0.45}$	9.08 ± 0.35 $1.23^{+0.30}_{-0.24}$	-0.16 ± 0.39 (9) $1.03^{+0.36}_{-0.27}$	-8.71 ± 0.31 (9) $0.57^{+0.31}_{-0.20}$
H-rich	16	0.21	21.20 ± 0.90 (15) $3.41^{+0.73}_{-0.60}$	0.80 ± 0.20 (11) $0.57^{+0.17}_{-0.13}$	-18.18 ± 0.70 $2.70^{+0.57}_{-0.47}$	8.74 ± 0.38 $1.37^{+0.29}_{-0.24}$	-0.45 ± 0.33 (12) $1.05^{+0.27}_{-0.24}$	-8.61 ± 0.23 (12) $0.46^{+0.32}_{-0.19}$
$0.5 < z \leq 1.0$								
H-poor	14	0.73	25.24 ± 0.54 (13) $1.86^{+0.47}_{-0.37}$	1.11 ± 0.07 (4) $0.03^{+0.05}_{-0.02}$	-17.66 ± 0.44 $1.52^{+0.34}_{-0.28}$	8.50 ± 0.24 $0.71^{+0.22}_{-0.17}$	-0.10 ± 0.19 $0.44^{+0.25}_{-0.16}$	-8.56 ± 0.21 $0.47^{+0.18}_{-0.13}$
$1.0 < z \leq 4.0$								
H-poor	12	1.67	25.38 ± 0.43 (11) $1.32^{+0.35}_{-0.27}$	1.59 ± 0.60 (5) $0.75^{+1.00}_{-0.43}$	-19.86 ± 0.68 $2.25^{+0.58}_{-0.46}$	8.91 ± 0.27 $0.77^{+0.24}_{-0.18}$	0.70 ± 0.30 $0.93^{+0.24}_{-0.19}$	-8.00 ± 0.23 $0.25^{+0.54}_{-0.17}$

Note. — The first row of each ensemble property shows the mean value and its error and the second row the standard deviation of the sample. The SFRs and sSFRs were extracted from the SED modelling and are corrected for attenuation. The H-poor and H-rich samples include all SLSNe irrespective of sub-type. ^(a) The number of objects with measured $R - K_s$ colour or with an $F625W/R/r'$ -band observation are given in parenthesis, if they are less than total number in sample.

^(b) SNe 1999bd and 2006gy are not considered in the sSFR and SFR calculation because their SFH cannot be modelled with a simple single stellar population model, while CSS100217 and PTF11dsf are excluded because of a possible AGN contamination.

D3) that both distributions are drawn from the same parent distribution. This result contradicts Japelj et al. (2016), who argued that previously claimed differences between the two populations are an artefact of the comparison methodology. We discuss this finding in Sec. 5.4.1 in detail. The population of SLSN-I host galaxies is also incompatible with that of ordinary core-collapse SNe from untargeted surveys at all redshifts ($p_{\text{ch}} < 4 \times 10^{-4}$; Figs. D2, D3). In contrast, the SLSN-IIIn host population is similar to the GRB population ($p_{\text{ch}} = 0.26$; Fig. D2).

4.3.2 $R - K_s$ colour

The middle panel of Fig. 7 shows the evolution of the $R - K_s$ colour of the 25 H-poor and 11 H-rich SLSN hosts with R and K_s -band observations. The colour varies between ~ -2 and 3 mag, though with large errors. No SLSNe are found in extremely red objects (EROs, $(R - K_s) \geq 3.3$ mag). At $z < 0.5$, SLSN-I hosts are characterised by significantly bluer average colours ($R - K_s = 0.07 \pm 0.16$ mag; Table 3) than star-forming galaxies from the UltraVISTA survey (grey shaded region; $R - K_s = 1.10 \pm 0.01$ mag; Table D1). The chance of randomly drawing a distribution from the UltraVISTA sample that is at least as extreme as the SLSN-I is $< 10^{-5}$ (Fig. D2). The average colour is $> 0.45 \pm 0.19$ mag bluer and statistically incompatible those extreme emission galaxies in the VUDS and zCOSMOS surveys ($p_{\text{ch}} < 1 \times 10^{-2}$; Fig. D2; Table 3). As redshifts increase,

the average colour increases to 1.59 ± 0.60 mag at $z > 1$, but still remains below the average colour of UltraVISTA galaxies (2.43 ± 0.01 mag; Tab. D1).

The average colour of hydrogen-rich SLSNe ($R - K_s = 0.80 \pm 0.20$ mag) is similar to that of average star-forming galaxies in the UltraVISTA sample and of GRB host galaxies (Tables 3, D1). While the dispersions of the brightness and luminosity distributions are broader than of other galaxy samples, the colour distribution has a comparable dispersion to all other samples [$\sigma(R - K_s) = 0.57^{+0.17}_{-0.13}$ mag; Tables 3, D1]. Hosts of type II SLSNe tend to be too faint to obtain meaningful K_s -band constraints, which prevents contrasting their properties to the ensemble of type IIIn SLSNe.

In the bottom panel of Fig. 7, we overlay expected colour-tracks for the stellar population synthesis templates from Bruzual & Charlot (2003) for a metallicity of $0.2 Z_\odot$ and a wide range of ages. The colour of SLSN-I hosts of ~ 0 mag at $z < 0.5$ points to single population ages of several up to a few hundred million years, whereas H-rich SLSNe are found in galaxies with more evolved stellar populations (ages being around several hundred million years). However, the exact relation between colour and age is a complicated function of metallicity, extinction, the equivalent width of emission lines and star-formation histories (for a detailed discussion see Conroy 2013), indicated by vectors in Fig. 7.

A critical aspect of this analysis is the R and K_s -band observing completeness. Almost all hosts were observed in

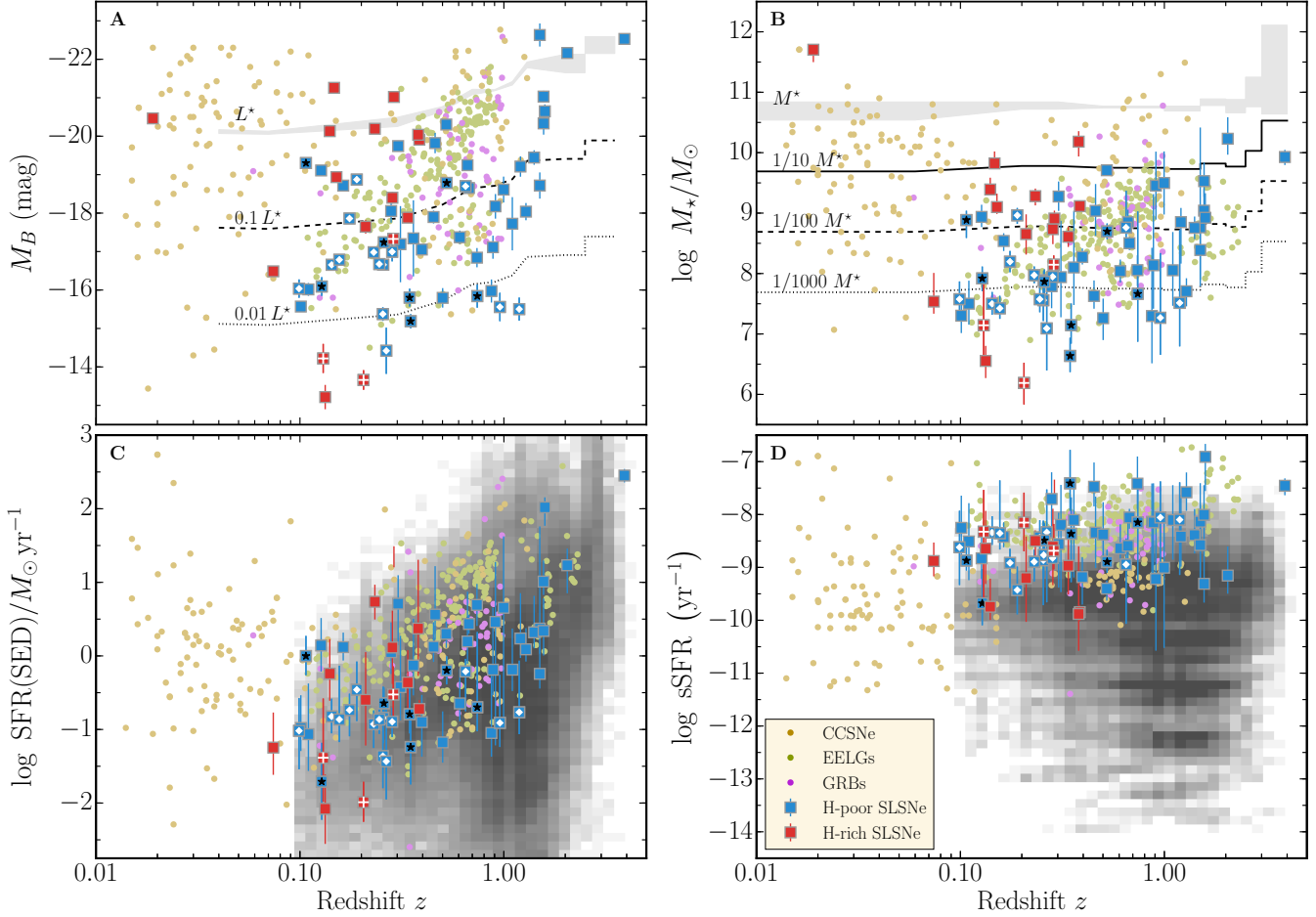


Figure 8. Evolution of the physical properties of SLSN host galaxies and comparison samples. Symbols are identical to previous figures. In panel A, we show the evolution of the characteristic luminosity L^* of the B -band luminosity function of blue galaxies, reported in Faber et al. (2007), Ilbert et al. (2005) and Marcesini et al. (2007) in grey, and several luminosity tracks. In panel B, we show the evolution of the characteristic mass M^* of the mass function from the GAMA (Baldry et al. 2012) and UltraVISTA surveys in grey, and several mass tracks. These characteristic masses and luminosities are defined where the power-law form of the Schechter function cuts off. The parameter space of the UltraVISTA sample is shown as grey-shaded density plot in all panels. For clarity, measurement errors are omitted for the comparison samples. They are comparable to those of the SLSN host galaxies.

R band, but only $\sim 57\%$ were observed in K_s band. The colour incompleteness is a direct consequence of the difficulty to obtain meaningful K_s -band constraints for hosts fainter than $K_s = 23$ – 24 mag. This is supported by the SED modelling, which always suggests K_s -band magnitudes below this detection limit and colours that are comparable to the observed colour distribution. If, in the unlikely case, the hosts without K_s -band observations would have $K_s = 23$ – 24 mag, the colour distribution would span a range from 0.3 to 4.7 mag. Such red colours are in stark contrast to the observed distribution, the SED modelling, and SN observations (e.g. Quimby et al. 2011c; Inserra et al. 2013; Lunnan et al. 2013; Nicholl et al. 2014).

4.4 Physical properties and distribution functions

In the following we take advantage of the full SUSHIES sample and present distribution functions of the primary diagnostics mass and SFR of H-poor and -rich SLSNe host galaxies.

¹² Figures 2, B1 and B2 show the best fit of each host galaxy and the evolution of the galaxy properties are shown in Fig. 8. Table 4 lists the model parameters. The evolution of the ensemble properties are summarised in Table 3.

4.4.1 Stellar mass

The masses of the host galaxies (panel B in Fig. 8), a key diagnostic of the SED modelling, extend from 10^6 to $10^{10} M_\odot$ for both classes of SLSNe. In a singular case, the stellar mass of a host exceeded $10^{11.7} M_\odot$ (SLSN-II in SN 2006gy). H-poor SLSNe are preferentially found in galaxies with average masses of $\sim 10^{7.9} M_\odot$ at $z = 0.5$. At higher redshifts the average masses gradually increase to $\sim 10^{8.9} M_\odot$ at $z > 1$, while the dispersion remains constant at 0.65 dex (Table 3). Using the parametrisation of the mass function in Muzzin

¹² We omit discussing the age of the stellar populations and their attenuation. In particular, the age is notoriously difficult to measure accurately and precisely.

Table 4. Results from the spectral energy distribution modelling

SLSN	Redshift	$\chi^2/\text{n.o.f.}$	$E(B - V)$ (mag; host)	M_{FUV} (mag)	M_{B} (mag)	M_{Ks} (mag)	log SFR ($M_{\odot} \text{ yr}^{-1}$)	log M (M_{\odot})	log sSFR (yr^{-1})	log Age (yr)
SLSN-I host galaxies										
CSS140925	0.460	0.32/4	0.50	-17.96 ± 0.24	-19.82 ± 0.26	< -21.12	$0.56^{+0.66}_{-0.34}$	$9.04^{+0.44}_{-0.41}$	$-8.34^{+0.68}_{-0.67}$	$8.37^{+0.57}_{-0.65}$
DES14S2qri	1.500	1.06/4	0.07	-18.19 ± 0.82	< -22.63	< -24.15	$0.37^{+1.39}_{-0.34}$	$8.76^{+1.65}_{-0.87}$	$-8.14^{+0.73}_{-1.07}$	$8.19^{+0.80}_{-0.69}$
DES14X2byo	0.869	0.00/2	0.30	-14.86 ± 0.99	< -15.97	< -16.71	$-1.05^{+0.83}_{-0.32}$	$7.30^{+1.13}_{-0.78}$	$-8.14^{+0.72}_{-1.06}$	$8.19^{+0.79}_{-0.68}$
DES14X3taz	0.608	4.78/8	0.00	-16.57 ± 0.20	-17.37 ± 0.17	-17.13 ± 0.19	$-0.65^{+0.48}_{-0.24}$	$8.04^{+0.19}_{-0.19}$	$-8.64^{+0.46}_{-0.34}$	$8.60^{+0.33}_{-0.39}$
iPTF13ajg [†]	0.740	0.00/1	0.00	-16.68 ± 0.21	< -15.84	< -15.08	$-0.70^{+1.02}_{-0.33}$	$7.66^{+1.36}_{-0.79}$	$-8.15^{+0.74}_{-1.15}$	$8.22^{+0.82}_{-0.71}$
LSQ12dlf [‡]	0.255	0.54/5	0.00	-14.72 ± 0.25	-15.38 ± 0.17	-15.91 ± 0.31	$-1.36^{+0.54}_{-0.43}$	$7.56^{+0.33}_{-0.34}$	$-8.86^{+0.75}_{-0.85}$	$8.73^{+0.73}_{-0.57}$
LSQ14an	0.163	5.60/10	0.01	-18.34 ± 0.26	-18.71 ± 0.09	-18.60 ± 0.11	$0.12^{+0.20}_{-0.18}$	$8.54^{+0.13}_{-0.17}$	$-8.42^{+0.27}_{-0.20}$	$8.48^{+0.20}_{-0.29}$
LSQ14mo [‡]	0.256	2.37/5	0.00	-15.92 ± 0.08	-16.66 ± 0.11	-16.95 ± 0.13	$-0.84^{+0.42}_{-0.34}$	$7.89^{+0.15}_{-0.19}$	$-8.77^{+0.62}_{-0.43}$	$8.67^{+0.35}_{-0.48}$
LSQ14bdq [‡]	0.345	5.77/5	0.00	-16.46 ± 0.21	-15.80 ± 0.23	< -14.09	$-0.79^{+0.39}_{-0.26}$	$6.64^{+0.30}_{-0.27}$	$-7.41^{+0.63}_{-0.52}$	$7.50^{+0.47}_{-0.76}$
LSQ14fxj	0.360	0.27/3	0.00	-18.40 ± 0.99	-17.34 ± 0.99	< -16.03	$-0.13^{+0.63}_{-0.41}$	$8.10^{+0.94}_{-0.62}$	$-8.10^{+0.71}_{-0.99}$	$8.16^{+0.83}_{-0.67}$
MLS121104	0.303	8.46/7	0.20	-18.18 ± 0.17	-18.74 ± 0.14	-20.57 ± 0.13	$0.71^{+0.39}_{-0.24}$	$9.27^{+0.25}_{-0.24}$	$-8.56^{+0.59}_{-0.57}$	$8.97^{+0.57}_{-0.63}$
PS1-10ky	0.956	0.01/4	0.20	-15.66 ± 0.99	-15.56 ± 0.37	< -13.73	$-0.91^{+0.56}_{-0.33}$	$7.27^{+1.07}_{-0.61}$	$-8.06^{+0.68}_{-0.99}$	$8.10^{+0.86}_{-0.63}$
PS1-10pm	1.206	0.30/4	0.50	< -17.61	-19.21 ± 0.26	-19.68 ± 0.09	$0.24^{+0.62}_{-0.26}$	$8.85^{+0.23}_{-0.69}$	$-8.42^{+0.79}_{-0.57}$	$8.45^{+0.52}_{-0.74}$
PS1-10ahf	1.158	3.98/5	0.30	-17.10 ± 0.25	-17.72 ± 0.99	-17.62 ± 0.99	$-0.19^{+0.56}_{-0.29}$	$8.05^{+0.59}_{-0.59}$	$-8.10^{+0.75}_{-0.98}$	$8.15^{+0.62}_{-0.63}$
PS1-10awh	0.909	0.09/4	0.50	< -14.11	-18.18 ± 0.32	-22.01 ± 0.28	$0.46^{+0.82}_{-1.68}$	$9.45^{+0.56}_{-0.56}$	$-9.22^{+0.98}_{-1.36}$	$8.97^{+0.63}_{-0.67}$
PS1-10bjz [‡]	0.649	51.95/5	0.00	-18.64 ± 0.09	-18.70 ± 0.12	-18.18 ± 0.17	$-0.21^{+0.16}_{-0.54}$	$8.76^{+0.61}_{-0.35}$	$-8.95^{+0.49}_{-1.12}$	$8.93^{+0.55}_{-0.41}$
PS1-11ap [†]	0.524	1.83/5	0.00	-18.00 ± 0.05	-18.79 ± 0.11	-18.55 ± 0.37	$-0.20^{+0.19}_{-0.19}$	$8.70^{+0.13}_{-0.13}$	$-8.89^{+0.22}_{-0.21}$	$8.71^{+0.28}_{-0.24}$
PS1-11tt	1.283	0.00/2	0.00	< -18.49	-18.04 ± 0.22	-17.24 ± 0.07	$0.09^{+0.29}_{-0.17}$	$7.71^{+0.22}_{-0.25}$	$-7.58^{+0.38}_{-0.35}$	$7.65^{+0.34}_{-0.40}$
PS1-11afv	1.407	0.00/2	0.10	< -18.70	-19.45 ± 0.19	-19.79 ± 0.09	$0.32^{+0.50}_{-0.22}$	$8.76^{+0.19}_{-0.19}$	$-8.39^{+0.49}_{-0.35}$	$8.42^{+0.29}_{-0.46}$
PS1-11aib	0.997	1.34/5	0.20	-15.62 ± 0.71	-18.61 ± 0.34	-21.11 ± 0.32	$0.65^{+0.97}_{-1.65}$	$9.50^{+0.52}_{-0.52}$	$-9.01^{+1.02}_{-1.52}$	$8.88^{+0.67}_{-0.84}$
PS1-11bam	1.565	0.56/5	0.02	-20.81 ± 0.14	-21.03 ± 0.15	-20.66 ± 0.15	$1.01^{+0.29}_{-0.18}$	$9.04^{+0.37}_{-0.37}$	$-8.01^{+0.56}_{-0.52}$	$8.04^{+0.52}_{-0.51}$
PS1-11bdn	0.738	31.69/5	0.50	-15.19 ± 0.11	-16.84 ± 0.25	< -16.49	$0.69^{+0.29}_{-0.13}$	$8.06^{+0.25}_{-0.12}$	$-7.42^{+0.51}_{-0.16}$	$7.50^{+0.45}_{-0.23}$
PS1-12zn	0.674	12.73/12	0.20	-17.76 ± 0.14	-18.65 ± 0.06	-19.37 ± 0.07	$0.43^{+0.13}_{-0.13}$	$8.50^{+0.11}_{-0.12}$	$-8.06^{+0.16}_{-0.21}$	$8.14^{+0.18}_{-0.18}$
PS1-12bmy	1.566	3.22/6	0.00	-18.96 ± 0.11	-20.33 ± 0.29	< -19.79	$0.34^{+0.44}_{-0.33}$	$9.53^{+0.31}_{-0.26}$	$-9.31^{+0.69}_{-0.36}$	$8.92^{+0.58}_{-0.42}$
PS1-12bqf	0.522	9.88/15	0.10	-18.55 ± 0.09	-20.30 ± 0.05	-21.14 ± 0.07	$0.30^{+0.19}_{-0.19}$	$9.71^{+0.04}_{-0.04}$	$-9.40^{+0.23}_{-0.23}$	$8.93^{+0.08}_{-0.05}$
PS1-13gt	0.884	0.00/1	0.00	< -18.13	< -17.11	< -16.04	$-0.19^{+0.84}_{-0.35}$	$8.14^{+1.18}_{-0.72}$	$-8.15^{+0.74}_{-1.11}$	$8.22^{+0.82}_{-0.71}$
PTF09atu	0.501	0.93/5	0.00	< -15.22	-15.80 ± 0.25	< -14.98	$-1.18^{+0.42}_{-0.27}$	$7.26^{+0.32}_{-0.36}$	$-8.38^{+0.61}_{-0.55}$	$8.40^{+0.47}_{-0.60}$
PTF09cnd [†]	0.258	2.67/6	0.00	-16.97 ± 0.32	-17.24 ± 0.08	-16.87 ± 0.46	$-0.64^{+0.21}_{-0.18}$	$7.87^{+0.20}_{-0.21}$	$-8.49^{+0.32}_{-0.31}$	$8.52^{+0.21}_{-0.31}$
PTF10hgi [‡]	0.099	7.40/7	0.01	-14.36 ± 0.24	-16.04 ± 0.24	-16.09 ± 0.18	$-1.02^{+0.44}_{-0.52}$	$7.58^{+0.29}_{-0.31}$	$-8.62^{+0.65}_{-0.71}$	$8.61^{+0.38}_{-0.61}$
PTF10vqv	0.452	0.51/6	0.07	-18.60 ± 0.12	-17.90 ± 0.17	-16.92 ± 0.99	$0.12^{+0.33}_{-0.21}$	$7.63^{+0.26}_{-0.21}$	$-7.48^{+0.46}_{-0.37}$	$7.55^{+0.36}_{-0.54}$
PTF11rks [‡]	0.190	8.72/9	0.00	-17.27 ± 0.50	-18.87 ± 0.07	-19.20 ± 0.41	$-0.46^{+0.38}_{-0.43}$	$8.96^{+0.12}_{-0.14}$	$-9.43^{+0.44}_{-0.46}$	$8.98^{+0.36}_{-0.31}$
PTF12dam [†]	0.107	24.66/13	0.00	-18.65 ± 0.19	-19.30 ± 0.05	-18.61 ± 0.32	$-0.00^{+0.27}_{-0.26}$	$8.89^{+0.15}_{-0.30}$	$-8.87^{+0.35}_{-0.19}$	$8.69^{+0.29}_{-0.36}$
SCP06F6 [‡]	1.189	0.00/1	0.02	-16.56 ± 0.21	< -15.50	< -14.19	$-0.77^{+0.70}_{-0.36}$	$7.51^{+1.21}_{-0.72}$	$-8.10^{+0.71}_{-1.05}$	$8.14^{+0.81}_{-0.66}$
SN1999as	0.127	17.97/11	0.10	-17.93 ± 0.28	-19.11 ± 0.08	-19.38 ± 0.13	$0.14^{+0.37}_{-0.35}$	$8.94^{+0.20}_{-0.17}$	$-8.83^{+0.48}_{-0.39}$	$8.65^{+0.33}_{-0.33}$
SN2005ap [‡]	0.283	10.52/10	0.00	-16.44 ± 0.10	-17.00 ± 0.25	-16.21 ± 0.36	$-0.89^{+0.19}_{-0.31}$	$7.95^{+0.11}_{-0.15}$	$-8.82^{+0.26}_{-0.21}$	$8.66^{+0.25}_{-0.22}$
SN2006oz	0.396	15.05/7	0.15	-15.50 ± 0.25	-17.05 ± 0.08	-17.53 ± 0.22	$-0.90^{+0.37}_{-0.47}$	$8.27^{+0.12}_{-0.12}$	$-9.18^{+0.52}_{-0.52}$	$8.89^{+0.41}_{-0.34}$
SN2007bi [†]	0.128	6.62/9	0.04	-14.52 ± 0.34	-16.09 ± 0.24	-15.73 ± 0.24	$-1.71^{+0.53}_{-0.52}$	$7.92^{+0.20}_{-0.21}$	$-9.68^{+0.65}_{-0.41}$	$8.88^{+0.15}_{-0.27}$
SN2009de	0.311	0.99/4	0.30	-16.50 ± 0.99	-17.19 ± 0.99	< -17.87	$-0.42^{+0.70}_{-0.45}$	$7.94^{+0.93}_{-0.66}$	$-8.20^{+1.04}_{-1.27}$	$8.26^{+0.74}_{-0.73}$
SN2009jh [†]	0.349	5.87/5	0.15	< -14.85	-15.19 ± 0.18	-15.70 ± 0.16	$-1.24^{+0.42}_{-0.51}$	$7.15^{+0.36}_{-0.30}$	$-8.36^{+0.69}_{-0.92}$	$8.42^{+0.60}_{-0.69}$
SN2010gx [‡]	0.230	2.85/5	0.00	-16.30 ± 0.06	-16.98 ± 0.06	-16.96 ± 0.05	$-0.93^{+0.14}_{-0.32}$	$7.97^{+0.14}_{-0.13}$	$-8.89^{+0.23}_{-0.37}$	$8.87^{+0.13}_{-0.30}$
SN2010kd	0.101	4.37/5	0.15	-15.83 ± 0.53	-15.57 ± 0.07	-15.22 ± 0.07	$-0.98^{+0.44}_{-0.31}$	$7.30^{+0.25}_{-0.29}$	$-8.25^{+0.61}_{-0.52}$	$8.30^{+0.40}_{-0.59}$
SN2011ep	0.280	0.02/4	0.15	-18.17 ± 0.41	< -18.05	< -16.02	$0.05^{+0.41}_{-0.36}$	$7.79^{+0.42}_{-0.36}$	$-7.71^{+0.51}_{-0.58}$	$7.74^{+0.59}_{-0.45}$
SN2011ke [‡]	0.143	2.70/6	0.00	-16.38 ± 0.09	-16.66 ± 0.06	-16.57 ± 0.27	$-0.82^{+0.24}_{-0.23}$	$7.50^{+0.20}_{-0.18}$	$-8.34^{+0.31}_{-0.23}$	$8.40^{+0.25}_{-0.33}$
SN2011kff [‡]	0.245	4.60/6	0.00	-16.41 ± 0.08	-16.68 ± 0.08	-15.72 ± 0.43	$-0.86^{+0.18}_{-0.22}$	$7.58^{+0.19}_{-0.20}$	$-8.43^{+0.33}_{-0.25}$	$8.43^{+0.24}_{-0.27}$
SN2012ii [†]	0.175	12.26/10	0.02	-16.82 ± 0.37	-17.86 ± 0.09	-17.19 ± 0.21	$-0.74^{+0.22}_{-0.36}$	$8.20^{+0.18}_{-0.17}$	$-8.92^{+0.27}_{-0.48}$	$8.68^{+0.27}_{-0.19}$
SN2013dg [‡]	0.265	0.11/3	0.80	-11.05 ± 0.68	-14.42 ± 0.60	< -17.15	$-1.43^{+0.80}_{-0.52}$	$7.09^{+0.82}_{-0.70}$	$-8.34^{+0.81}_{-1.32}$	$8.35^{+1.09}_{-0.78}$
SN2013hy	0.663	0.31/4	0.01	-18.39 ± 0.14	-19.25 ± 0.11	-19.06 ± 0.18	$0.20^{+0.68}_{-0.30}$	$8.85^{+0.21}_{-0.19}$	$-8.59^{+0.62}_{-0.42}$	$8.56^{+0.39}_{-0.54}$
SN2015bn	0.110	8.18/6	0.30	-14.81 ± 0.59	-16.02 ± 0.17	-17.27 ± 0.41	$-1.06^{+0.69}_{-0.50}$	$7.50^{+0.38}_{-0.35}$	$-8.51^{+0.72}_{-0.73}$	$8.52^{+0.50}_{-0.66}$
SN1000+0216	3.899	42.94/11	0.30	-21.52 ± 0.08	-22.53 ± 0.08	-23.65 ± 0.28	$2.45^{+0.09}_{-0.09}$	$9.93^{+0.13}_{-0.13}$	$-7.46^{+0.18}_{-0.18}$	$7.53^{+0.16}_{-0.21}$
SN2213-1745	2.046	0.34/6	0.02	-21.00 ± 0.05	-22.16 ± 0.13	-21.44 ± 0.13	$1.23^{+0.23}_{-0.38}$	$10.23^{+0.36}_{-0.26}$	$-9.15^{+0.55}_{-0.34}$	$8.90^{+0.43}_{-0.41}$
SLS06D4deu	1.588	2.47/7	0.30	-20.00 ± 0.05	-20.65 ± 0.18	< -19.34	$2.02^{+0.14}_{-0.25}$	$8.92^{+0.41}_{-0.25}$	$-6.91^{+0.25}_{-0.65}$	$6.96^{+0.65}_{-0.27}$
SLS07D2bv	1.500	5.34/9	0.00	-17.66 ± 0.20	-18.72 ± 0.34	-19.23 ± 0.60	$-0.24^{+0.35}_{-0.20}$	$8.39^{+0.62}_{-0.60}$	$-8.58^{+0.76}_{-0.79}$	$8.57^{+0.74}_{-0.68}$
SSS120810 [‡]	0.156	5.20/7	0.00	-16.61 ± 0.18	-16.79 ± 0.11	-15.80 ± 0.24	$-0.86^{+0.73}_{-0.31}$	$7.42^{+0.21}_{-0.17}$	$-8.35^{+1.00}_{-0.31}$	$8.27^{+0.30}_{-0.82}$
SLSN-II in host galaxies										
CSS100217	0.147	78.34/11	0.50	-19.64 ± 0.09	-21.26 ± 0.05	-21.76 ± 0.05	$2.35^{+0.24}_{-0.07}$	$9.82^{+0.20}_{-0.17}$	$-7.46^{+0.10}_{-0.11}$	$7.53^{+0.08}_{-0.05}$
PTF10heh	0.338	2.97/7	0.15	-15.84 ± 0.21	-17.88 ± 0.09	-18.66 ± 0.13	$-0.36^{+0.44}_{-0.41}$	$8.61^{+0.17}_{-0.17}$	$-8.97^{+0.56}_{-0.54}$	$8.87^{+0.60}_{-0.47}$
PTF10qaf	0.284	0.49/6	0.00	-17.71 ± 0.16	-18.40 ± 0.15	-18.98 ± 0.19	$0.11^{+0.50}_{-0.50}$	$8.73^{+0.22}_{-0.22}$	$-8.61^{+0.71}_{-0.71}$	$8.63^{+0.69}_{-0.67}$
PTF11dsf	0.385</									

Table 4 – *continued* Results from the spectral energy distribution modelling

SLSN	Redshift	$\chi^2/\text{n.o.f.}$	$E(B - V)$ (mag; host)	M_{FUV} (mag)	M_{B} (mag)	M_{Ks} (mag)	$\log \text{SFR}$ ($M_{\odot} \text{ yr}^{-1}$)	$\log M$ (M_{\odot})	$\log \text{sSFR}$ (yr^{-1})	$\log \text{Age}$ (yr)
SLSN-IIn host galaxies (continued)										
SN2008fz	0.133	1.53/6	0.01	-12.43 ± 0.55	-13.22 ± 0.32	-13.56 ± 0.08	$-2.08^{+0.47}_{-0.48}$	$6.55^{+0.25}_{-0.28}$	$-8.64^{+0.71}_{-0.67}$	$8.62^{+0.41}_{-0.62}$
SN2009nm	0.210	2.39/5	0.15	-14.61 ± 0.21	-17.65 ± 0.18	-17.71 ± 0.21	$-0.60^{+0.65}_{-0.62}$	$8.65^{+0.33}_{-0.34}$	$-9.20^{+0.79}_{-0.83}$	$8.95^{+0.62}_{-0.52}$
SN2011cp	0.380	10.25/9	0.30	-16.90 ± 0.28	-20.04 ± 0.14	-21.79 ± 0.08	$0.37^{+0.93}_{-0.64}$	$10.18^{+0.17}_{-0.25}$	$-9.88^{+1.28}_{-0.70}$	$9.53^{+0.32}_{-0.89}$
SLSN-II host galaxies										
CSS121015 [‡]	0.287	0.97/6	0.00	-16.70 ± 0.08	-17.33 ± 0.07	-17.53 ± 0.29	$-0.52^{+0.38}_{-0.29}$	$8.15^{+0.15}_{-0.17}$	$-8.69^{+0.51}_{-0.35}$	$8.65^{+0.33}_{-0.43}$
SN2008es [‡]	0.205	0.84/4	0.00	-12.95 ± 0.30	-13.66 ± 0.25	-12.79 ± 0.40	$-1.99^{+0.28}_{-0.27}$	$6.19^{+0.33}_{-0.36}$	$-8.15^{+0.57}_{-0.54}$	$8.19^{+0.43}_{-0.53}$
SN2013hx [‡]	0.130	1.55/3	0.50	-12.04 ± 0.38	-14.22 ± 0.38	-16.43 ± 0.33	$-1.38^{+0.81}_{-0.60}$	$7.14^{+0.71}_{-0.67}$	$-8.33^{+0.79}_{-1.32}$	$8.38^{+1.10}_{-0.77}$

Note. — The absolute magnitudes are not corrected for host reddening, to compare those measurements with luminosity functions from flux-limited surveys. The star-formation rates are corrected for host reddening. The host attenuation was modelled with the Calzetti model. The abbreviation ‘n.o.f.’ stands for number of filters. The age refers to the age of the young stellar population. Objects with measured decline time-scale are marked by a [†]/_‡ if their decay is slower/faster than 50 days. For details on the fitting, see Sect. 3.3.

et al. (2013), these average masses correspond to $1/500 M^*$ and $1/50 M^*$ at $z \sim 0.5$ and $z \sim 1$, respectively.

H-rich SLSNe probe a significantly larger portion of the parameter space of star-forming galaxies in the UltraVISTA survey. Their distribution is not only shifted by 0.8 dex to larger masses but it also includes three hosts that are even less massive than the least massive SLSN-I host. The dispersion is ~ 0.8 dex broader compared to the H-poor sample and even ~ 0.5 dex broader compared to the UltraVISTA survey (Tables 3, D1). Despite the larger dispersion, the probability to randomly draw a distribution that is least as extreme as the H-rich population from the UltraVISTA sample is 25% and hence does not point to significant difference to general population of star-forming galaxies (Fig. D2).

Most remarkable about the distributions of H-poor and -rich SLSN host galaxies is the dearth of hosts above $10^{10} M_{\odot}$. Assuming that SLSNe are unbiased tracers of star-formation, we would in fact expect $\sim 40\%$ of all galaxies to have to have masses above $10^{10} M_{\odot}$. For H-poor SLSNe, the chance to draw such a distribution from the UltraVISTA sample is $< 10^{-5} \%$ at all redshifts (Fig. D2). The lack of massive galaxies strongly argues for a stifled production efficiency of H-poor SLSNe in massive galaxies (see also Perley et al. 2016b). We investigate this bias in detail in Sect. 5.2.

As in Sect. 4.3, we divide the SLSN-I sample according to their decay time scale. The mass distribution of fast- and slow-declining SLSNe are statistically identical ($p_{\text{ch}} = 0.72$; Fig. D2). On the other hand, the host distribution of SLSN-IIn and SLSN-II host galaxies appear to be different. SLSN-IIn host galaxies are characterised by an average mass of $\sim 10^{9.1 \pm 0.4} M_{\odot}$, whereas SLSNe-II are found in 1.8 ± 1.0 dex less massive galaxies (Tables 3). While larger samples are clearly needed, it is intriguing that two of three SLSNe-II exploded in galaxies with masses between 10^6 and $10^7 M_{\odot}$. These hosts are among the least massive galaxies in our sample.

4.4.2 Star-formation rate

Panel C in Fig. 8 displays the evolution of the dust-corrected star-formation rate (SFR). As redshift increases, the average SFR of SLSN-I hosts increases from $\log \text{SFR}/(M_{\odot} \text{ yr}^{-1}) =$

-0.61 ± 0.12 at $z < 0.5$ to 0.70 ± 0.30 at $z > 1$ (Table 3). In singular cases the SFR reaches $> 100 M_{\odot} \text{ yr}^{-1}$ (SN1000+0216 and SNLS06D4eu, Table 8). The dispersion of the distribution remains at 0.4 dex up to $z < 1$ and then increases to 0.9 dex at higher redshifts. The star-formation rates at $z > 0.5$ are similar to GRB and ordinary core-collapse SN host galaxies.

Hosts of H-rich SLSNe have comparable SFRs [$\Delta \log \text{SFR}/(M_{\odot} \text{ yr}^{-1}) = -0.45 \pm 0.33$; Table 3]. After separating out the three SLSN-II hosts, the population of SLSNe-IIn have marginally larger average SFRs [$\Delta \log \text{SFR}/(M_{\odot} \text{ yr}^{-1}) = -0.16 \pm 0.39$]. SLSN-II hosts have significantly lower SFR but their values are comparable to SLSN-I hosts [$\log \text{SFR}/(M_{\odot} \text{ yr}^{-1}) = -1.27 \pm 0.72$; Table 3]. Characteristic of the type IIn population is again the large dispersion of $1.03^{+0.36}_{-0.27}$, which is ~ 0.17 dex larger compared to the UltraVISTA sample ($p_{\text{ch}} = 10^{-4}$; Fig. ??; Table D1). No other class of transient host galaxies (GRBs and SNe) shows such large dispersion (Fig. D2).

To better understand the peculiarities of SLSN host galaxies, we normalise the SFR by the stellar mass (specific SFR, hereafter sSFR; panel D in Fig. 8). Hosts of both families of SLSNe are characterised by an average specific sSFR between $\log \text{sSFR}/\text{yr}^{-1} = -8.0$ and -8.7 at all redshifts, which is a factor > 10 larger than those of star-forming galaxies from the UltraVISTA survey at all redshifts ($\log \text{sSFR}/\text{yr}^{-1} \sim -10.0$; Fig. 8; Table D1). The probability of randomly drawing a population at least as extreme as the H-poor or the H-rich population from the UltraVISTA sample is $< 10^{-5}$ at all redshifts (Fig. D2). While the hosts of GRBs and ordinary SN host galaxies have sSFR intermediate between the SLSN-I host and the UltraVISTA samples, the SLSN-I host population is still statistically distinct ($p_{\text{ch}} < 10^{-2}$; Table D2, D3). In fact, their hosts are more comparable to EELGs from the VUDS survey and at higher redshifts with EELGs from the 3D-HST and WISPS surveys (Figs. D2–D4).

4.5 A radio perspective on SLSN host galaxies

Radio emission from star-forming galaxies is an excellent tracer of the total SFR (Condon 1992; Schmitt et al. 2006; Murphy et al. 2011; Calzetti 2013). In contrast to SED mod-

Table 5. Properties of the stacked VLA FIRST data

Redshift interval	Number	r.m.s. ($\mu\text{Jy}/\text{beam}$)	$\log \text{SFR}(\text{tot.})$ ($M_{\odot} \text{yr}^{-1}$)	$\log \text{SFR}(\text{SED})$ ($M_{\odot} \text{yr}^{-1}$)
H-poor SLSN host galaxies				
$z \leq 0.5$ ($\langle z \rangle = 0.26$)	17	42.5	< 1.11	-0.61 ± 0.12
$0.5 < z \leq 1.0$ ($\langle z \rangle = 0.74$)	12	44.2	< 1.96	-0.10 ± 0.19
$1.0 < z \leq 4.0$ ($\langle z \rangle = 1.41$)	9	56.3	< 2.51	0.68 ± 0.30
H-rich SLSN host galaxies				
$z \leq 0.5$ ($\langle z \rangle = 0.21$)	13	49.4	< 1.00	-0.44 ± 0.36
H-poor and H-rich SLSN host galaxies				
$z \leq 0.5$ ($\langle z \rangle = 0.23$)	30	32.2	< 0.90	-0.42 ± 0.17

Note. — The r.m.s. level was calculated from the stacked VLA FIRST image and converted into a 4σ limit on the total unobscured star-formation rate at the median redshift of each sample. That value represents a limit on the average total SFR. The weighted means of the SED-derived SFR is reported for comparison. For details see Sect. 4.5. The second value in the redshift column reports the mean redshift of each redshift interval.

elling and emission-line diagnostics, e.g., Balmer lines, it is independent of any extinction correction, although radio SFRs do suffer from time-delay for SNe to explode and create sufficient cosmic rays.

Almost all hosts lie in the footprints of wide-field radio surveys, such as VLA FIRST, NVSS and SUMSS. All hosts evaded detection in individual images down to the nominal r.m.s. levels of the surveys: FIRST ~ 0.15 mJy/beam, NVSS ~ 0.45 mJy/beam and SUMSS ~ 1.3 mJy/beam (see Table A2 for the individual measurements). To place tighter constraints on the average radio brightness of the host populations, we stack the data of the 51 fields with VLA FIRST data. We first divide the sample into three redshift bins ($z \leq 0.5$, $0.5 < z \leq 1.0$ and $z > 1$) and according to the SN type. Afterwards we centre the images on the supernova positions and median-combine them. Also in the stacks no host population is detected down to an r.m.s. of 32–60 $\mu\text{Jy}/\text{beam}$ at all redshifts (Table 5).

Following the method in Michałowski et al. (2009), we translate the flux density into SFR limits.¹³ The non-detections correspond to 4σ SFR limits between $8.0 M_{\odot} \text{yr}^{-1}$ at $z \sim 0.23$ to $326 M_{\odot} \text{yr}^{-1}$ at $z \sim 1.41$, and exceed the SED-derived SFRs by factors 21 to 120 (Table 5). This allows ruling out truly extreme obscured star formation, in agreement with the observed $R - K_s$ colours and the absence of reddened SLSNe in our sample.

In addition to the survey data, the hosts of MLS121104, SN2005ap and SN2008fz were targets of our JVLA campaign. All three hosts evaded detection down to nominal r.m.s. values of 15, 25 and 15 $\mu\text{Jy}/\text{beam}$ for MLS121104, SN2005ap and SN2008fz, respectively. Those limits correspond to 4σ SFR limits of 6.2, 9.0 and $1.6 M_{\odot} \text{yr}^{-1}$, respectively. The limit on MLS121104 is of particular inter-

est. It is the only known host with a super-solar metal abundance. The SED modelling revealed a dust-corrected SFR of $5.13^{+7.46}_{-3.72} M_{\odot} \text{yr}^{-1}$ (Table 4), which is comparable to the radio limit within errors, implying that the optical diagnostics probed the total star formation activity in the galaxy. The limits on the hosts of SNe 2005ap and 2008fz exceed the SED-SFRs by at least a factor of 50 and hence are less constraining; the SED-inferred SFRs of these hosts are very low (SN2005ap: $0.13^{+0.07}_{-0.05} M_{\odot} \text{yr}^{-1}$, SN2008fz: $0.01^{+0.02}_{-0.01} M_{\odot} \text{yr}^{-1}$; Table 4).

5 DISCUSSION

5.1 Evolution of SLSN-I host galaxies

We first quantify how mass, FUV luminosity (as a tracer of the SFR) and the B -band luminosity of the SLSN-I host population evolve throughout cosmic time. The redshift evolution of these diagnostics is displayed in Fig. 9 (left panels). To quantify their redshift evolution, we fit the data with the linear model $Y = A + B \log(1 + z)$ and propagate errors through a MC simulation and bootstrapping as described in Sect. 3.4.

The left panels in Fig. 9 show the best fits and their 1σ error contours. The mass, FUV and the B -band luminosity of SLSN-I hosts show a moderate to strong redshift dependence with a linear correlation coefficient between $|r| = 0.5$ and $|r| = 0.6$ (Table 6). The probability of generating each of these linear correlations by chance is between 4×10^{-5} and 3.5×10^{-6} , respectively (~ 4.0 – 4.5σ ; Table 6).

To isolate the differential evolution of SLSN host galaxies from known global trends, we repeat the analysis after subtracting the evolution of the mass function, and the FUV and B -band luminosity functions of star-forming galaxies. As tracers for the secular evolution, we use the characteristic luminosities and masses of the luminosity and mass functions: FUV: Wyder et al. (2005) and Cucciati et al. (2012); B band: Madgwick et al. (2002), Faber et al. (2007) and Marchesini et al. (2007); and mass: Baldry et al. (2012), Muzzin et al. (2013) and Grazian et al. (2015).

The right panels in Fig. 9 show the redshift evolution of the host properties after detrending. The strong redshift evolution in the B band and the FUV is consistent with the general cosmic evolution of star-forming galaxies. After detrending the data, the differential evolution in the FUV and B band is consistent with no evolution. The chance probability increases from $< 4 \times 10^{-5}$ to $> 2 \times 10^{-2}$ (i.e., $< 3\sigma$; Table 6). The galaxy mass, on the other hand, still shows a moderate redshift dependence, though with a significantly higher chance probability of 1.1×10^{-4} (equivalent to 3.9σ ; Table 6).

Intriguingly, the rate with which the stellar mass of SLSN-I host galaxies increases with redshift before and after detrending is similar to the redshift dependence of the characteristic mass in the mass-metallicity relation [$\Delta M / \Delta \log(1 + z) \sim 2.64$; Zahid et al. 2014]. This suggests that metallicity is a regulating factor in the SLSN production (as argued by Chen et al. (2016) and Perley et al. 2016b). In the following section we investigate this relationship in detail.

Due to the small redshift range probed by our H-rich

¹³ This method is based on Bell (2003) and assumes a power-law shaped radio continuum with a spectral index of $\alpha = -0.75$ ($F_{\nu} \propto \nu^{\alpha}$; Condon 1992; Ibar et al. 2009).

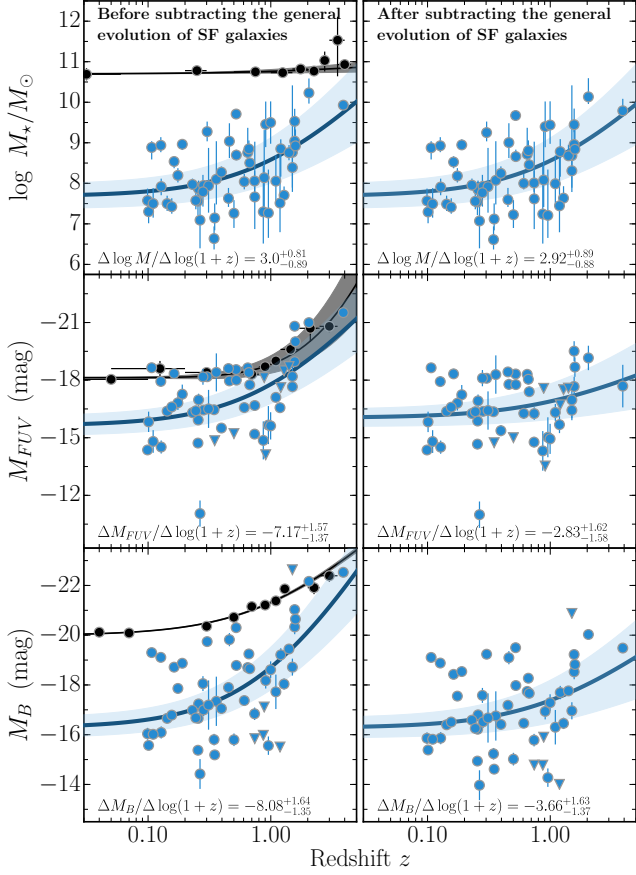


Figure 9. Mass, FUV luminosity at 1500 Å (as proxy of the observed SFR) and B -band luminosity plotted vs. redshift (detections: \bullet ; non-detections: \blacktriangledown). The observed evolution (left panels) is the sum of the differential evolution of SLSN-I host galaxies and the general cosmic evolution of star-forming galaxies. This general cosmic evolution is indicated by the evolution of the characteristic luminosity and mass of appropriate luminosity and mass functions (black data points; x-errors indicate the redshift intervals of the luminosity and mass functions). The right panels display the differential evolution of SLSN-I host galaxies after detrending. Each data set was fitted with the linear model $Y = A + B \log(1+z)$. The curves represent the best fit and the shaded regions the 1σ error contour. The slopes of the best fits are displayed at the bottom of the panels. Note the significant change in the redshift evolution of the FUV and B -band luminosity after detrending, while the evolution of the galaxy mass remains unchanged.

SLSN sample, the redshift dependence of their physical properties is inconclusive.

5.2 Metallicity bias

5.2.1 Dependence of SLSN formation on host galaxy mass

To quantify the effect that the physical parameters of SLSN host galaxies have on SLSN formation, we contrast the galactic environments of SLSN explosions to those of star formation in general. In addition to our SLSN host data, we hence require a census of cosmic star-formation in the respective redshift range as complete as possible. Fortunately, numer-

Table 6. Redshift evolution of SLSN-I host galaxies

Property	Linear correlation		Linear model	
	r	p_{ch}	slope	intercept
Before removing the cosmic evolution of SF galaxies				
Mass	$0.52^{+0.13}_{-0.18}$	7.7×10^{-5}	$3.00^{+0.81}_{-0.89}$	$7.68^{+0.30}_{-0.31}$
M_{FUV}	$-0.53^{+0.13}_{-0.10}$	4.0×10^{-5}	$-7.17^{+1.57}_{-1.37}$	$-15.63^{+0.53}_{-0.50}$
M_B	$-0.59^{+0.13}_{-0.10}$	3.5×10^{-6}	$-8.08^{+1.64}_{-1.35}$	$-16.28^{+0.41}_{-0.40}$
After removing the cosmic evolution of SF galaxies				
Mass	$0.51^{+0.14}_{-0.18}$	1.1×10^{-4}	$2.92^{+0.89}_{-0.88}$	$7.68^{+0.29}_{-0.31}$
M_{FUV}	$-0.24^{+0.14}_{-0.13}$	7.7×10^{-2}	$-2.83^{+1.62}_{-1.58}$	$-16.04^{+0.46}_{-0.44}$
M_B	$-0.32^{+0.15}_{-0.13}$	2.1×10^{-2}	$-3.66^{+1.63}_{-1.37}$	$-16.28^{+0.41}_{-0.40}$

Note. — The two set of fits show the redshift evolution before and after correction for global trends of star-forming (SF) galaxies. The columns of the linear correlation analysis display the linear correlation coefficient r , and the corresponding chance probability p_{ch} . The redshift evolution is parametrised with the linear model $Y = A + B \log(1+z)$.

ous deep-field photometric galaxy surveys compiled in recent years provide a good match to our SLSN imaging data.

The deepest surveys that probe a sufficient cosmic volume are COSMOS (Scoville et al. 2007) and CANDELS (Grogin et al. 2011); both have a high completeness levels for galaxies above stellar masses of $M_* \gtrsim 10^8 M_\odot$ at $z \sim 0.5$ (e.g., Tomczak et al. 2014). This is still two orders of magnitude higher than our least massive SLSN hosts (Table 4). We assume these uncertainties to be small because the mass and luminosity functions of star-forming galaxies are rather well constrained and no hints for a plunging of the stellar-mass and luminosity functions were detected yet.

The primary parameter that we are interested in is galaxy stellar mass M_* , because it is known to correlate well with the average galaxy metallicity. Metallicity, in turn, has a strong effect on the evolution of massive stars through line-driven stellar winds. Similar considerations have previously been applied to GRB hosts, where after a long debate, the impact of metallicity on long GRB-selected galaxies is now relatively robustly established (e.g., Krühler et al. 2015; Schulze et al. 2015; Vergani et al. 2015; Perley et al. 2016c).

In addition to galaxies from wide-field surveys, we also compare the mass distribution of our SLSN hosts to those other star-forming galaxies: to those selected through GRBs (Hjorth et al. 2012; Perley et al. 2016a) and low- or high-redshift core-collapse supernovae from untargeted surveys (Svensson et al. 2010; Stoll et al. 2013). The latter is a particularly suitable control sample, as normal CCSNe are thought to trace all star-forming environments in a relatively direct and unbiased way (Stoll et al. 2013). For simplicity and the sake of clarity, we do not differentiate between CCSNe subtypes.

As we showed in Sect. 4.4.1, hydrogen-poor SLSNe trace the least massive systems. The median stellar mass increases towards GRB hosts and galaxies selected by more frequent CCSNe (Fig. D). A simple AD test between GRB and SLSN-I host galaxies at $0.3 < z < 1.0$ rejects the notion that long GRBs and SLSN-I have similar host mass distributions ($p_{\text{ch}} < 2 \times 10^{-3}$; Fig. D3), and shows that GRB hosts are on average substantially fainter than galaxies hosting normal CCSNe. It is thus immediately obvious that a strong effect

prevents SLSN-I to form in galaxies of high stellar mass. At $z < 1$, none of the SLSN-I hosts in our sample of 41 events has a stellar mass above $10^{10} M_{\odot}$, whereas $\sim 40\%$ of CCSNe form in such massive galaxies.

SLSN-II are, as noted previously (Leloudas et al. 2015c; Perley et al. 2016b), 0.8 dex more massive than their H-poor counterparts, and comparable to GRB hosts, effectively tracing (within the limited number statistics) a similar mass distribution. Again, we also find here a lack of massive hosts about $10^{10} M_{\odot}$, like for SLSN-I hosts.

5.2.2 SLSNe are biased tracers of SFR

Under the working hypothesis that massive stars are the progenitors of SLSNe, they should also trace the star-formation rate in a particular way. Previous experience with GRB hosts has however illustrated that environmental factors, most commonly attributed to a low progenitor metallicity, can have a significant effect (e.g., Graham & Fruchter 2013; Schulze et al. 2015; Perley et al. 2016b). This effect is presumably even stronger in SLSN-selected galaxies, considering their the mass distributions (Fig. D2; Tables 3, D1)

To better illustrate the efficiency of SLSN production with host stellar mass (or metallicity), we need to normalise the number of SLSN-selected galaxies by the contribution of similar massive systems to the cosmic star-formation at the given redshifts. We derive this by starting with the stellar mass function $\Phi(M)dM$ of star-forming galaxies from CANDELS. This yields the number density of galaxies per stellar mass bin. We use the parametrisation of Φ for star-forming galaxies from Table 2 of Tomczak et al. (2014), and note that the rather similar stellar-mass functions from Ilbert et al. (2013) or Muzzin et al. (2013) do not alter our conclusions significantly.

We then sum the star-formation rate of all contributing galaxies by integrating over the scatter of all galaxies in the galaxy main sequence at a given stellar mass (e.g., Whitaker et al. 2012; Sobral et al. 2014; Speagle et al. 2014; Tasca et al. 2015). The SFR-weighted mass histogram, shown in Fig. 10 in yellow, peaks at around $10^{9.5-10.5} M_{\odot}$, and provides a good match to the sample of host galaxies of CCSN selected through untargeted surveys. The stellar mass histogram (Fig. 10, again normalised to one unit area) of CCSNe is consistent with the upper theoretical expectation within bootstrapped errors, which gives us confidence that our procedure is adequate.

In contrast, the mass histogram of SLSN-hosting galaxies peaks two orders of magnitudes lower, clearly inconsistent with the typical environments where the bulk of the stars are produced at $z \sim 0.5$.

5.2.3 SLSNe production efficiency

We modelled the SLSN host stellar mass histogram by applying a function that describes an efficiency factor $\rho(M)$ of producing SLSN from star-formation depending on the host stellar mass. We chose $\rho(M)$ as an exponential function in the form of $\rho = \exp(-\beta M/M_0)$, where M_0 is a characteristic cut-off mass where the production efficiency dropped to $1/e$, and β a cut-off strength. This essentially shuts off SLSN production in galaxies of high stellar mass. Physically,

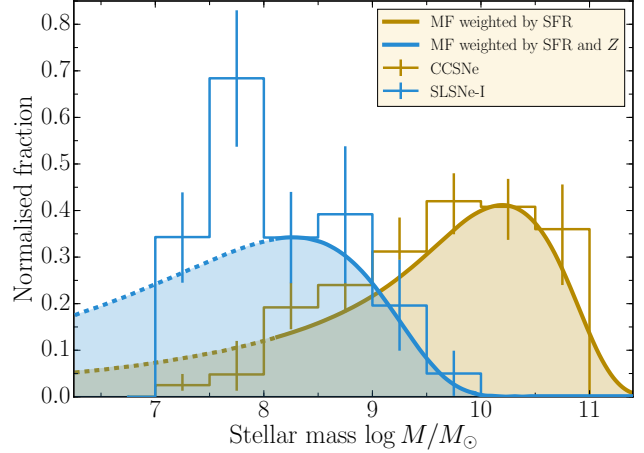


Figure 10. Histogramme of the mass distribution of H-poor SLSN host galaxies and hosts of CCSNe from the Stoll et al. (2013) sample at $z < 1$. The area of each histogram is normalised to unity. The yellow curve shows the SFR-weighted CANDELS mass. This model describes the observed distribution for CCSNe reasonably well. To match the distribution of H-poor SLSN host galaxies, a further weighting is required that stifles the SLSN production in high-mass galaxies. This mass-dependent (i.e., metallicity dependent) production efficiency can be crudely modelled by an exponential metallicity cut-off at $12 + \log \text{O}/\text{H} = 8.31^{+0.16}_{-0.30}$ (blue curve). The dashed line of the model fit indicates the mass regime where the CANDELS mass function (MF) had to be extrapolated.

this can be interpreted as a decrease in the probability of creating SLSNe-I from massive stars above a characteristic cut-off metallicity, where we assume that stellar mass at a given star-formation rate relates to host metallicity at stellar masses below $\sim 10^{10} M_{\odot}$ (e.g., Mannucci et al. 2010; Yates et al. 2012).

We then minimise the deviation between model and data by varying M_0 and β using a MC method on 10^5 bootstrapped distributions of SLSN-I host masses derived from our parent sample. Statistical errors on host masses are included in the procedure by varying them according to the uncertainties in Table 4 within each trial. The best-fit model is obtained at M_0 corresponding to $12 + \log(\text{O}/\text{H})_0 = 8.31^{+0.16}_{-0.26}$ and $\beta = 2.1$. While our procedure can constrain $12 + \log(\text{O}/\text{H})_0$ relatively accurately, the cut-off shape is not yet well measured. Acceptable fits are obtained in a range between $\beta = 1$ and $\beta > 30$, where the latter illustrates an infinitely sharp cutoff at $12 + \log(\text{O}/\text{H})_0 = 8.4$. Of course, the parameters M_0 and β are not fully independent. The higher the cut-off mass, the sharper the cutoff. Figure 11 hence shows the best-fit and a region which contains 68% of all MC trials.

For comparison, we modelled the mass distribution of our GRB host galaxy sample with the same model (purple curve in Fig. 11). Their mass distribution points to a higher metallicity cut-off at $12 + \log(\text{O}/\text{H})_0 \sim 8.6 \pm 0.10$ (i.e., a 0.3 dex larger oxygen abundance than SLSN-I host galaxies), in agreement with Krühler et al. (2015) and marginally lower than Perley et al. (2016b).

For SLSNe-II, number statistics are still too low to derive robust constraints, but the host mass distribution indicates a behaviour similar to that observed for GRB hosts.

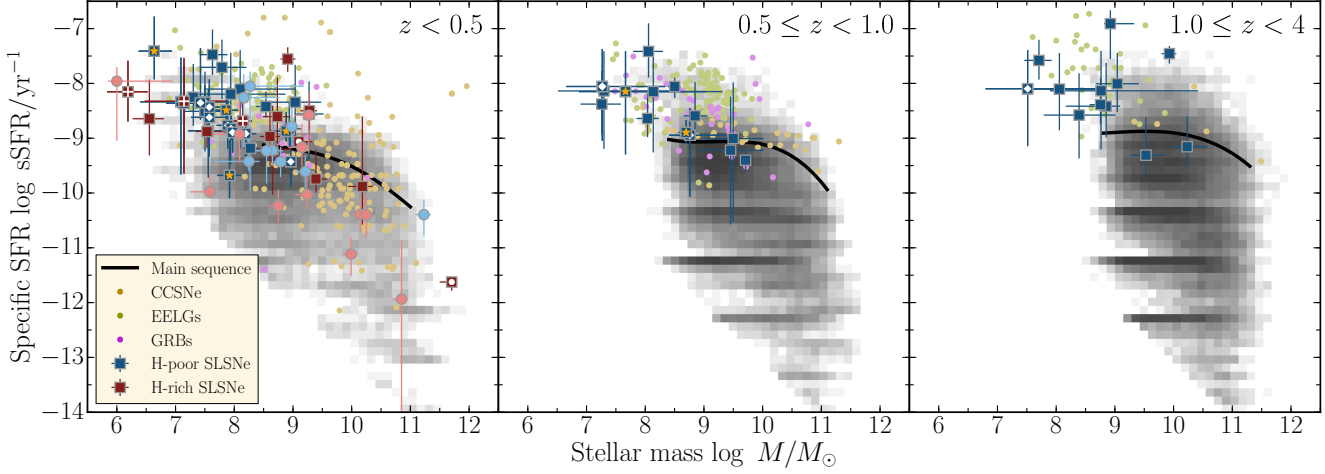


Figure 12. Specific star-formation rate versus stellar mass in three different redshift intervals. Overlaid is the locus of star-forming galaxies from the UltraVISTA survey (grey shaded area). Colour coding is identical to previous figures. The dark-red squares with white dots show the location of the SLSN-II SN 1999bd and 2006gy, using their $H\alpha$ and IR luminosity as SFR indicators, respectively (taken from [Smith et al. 2007](#) and [Leloudas et al. 2015c](#)). The samples in light blue and red show the location of hosts in [Perley et al. \(2016b\)](#). Note the huge diversity of the SLSN-II host population. Measurement errors are omitted for comparison samples. They are similar to that of SLSN host galaxies. The black curve shows the location of the galaxy main sequence in each redshift bin. Their values were taken from [Whitaker et al. \(2014\)](#) and [Lee et al. \(2015\)](#).

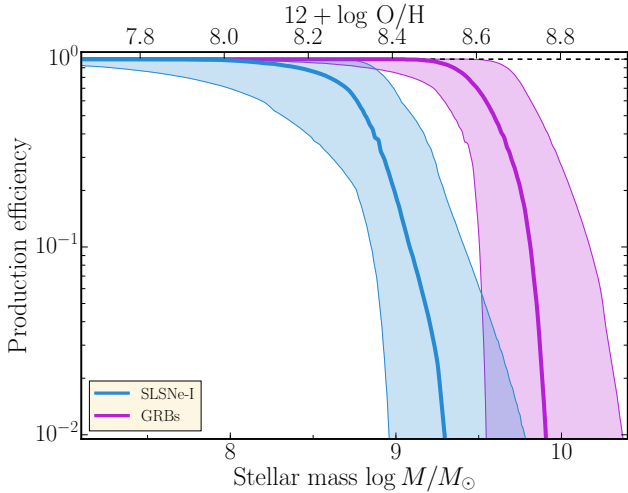


Figure 11. Production efficiency of H-poor SLSNe in galaxies with stellar mass M . Applying the mass-metallicity relation in [Mannucci et al. \(2011\)](#) maps a given mass of a galaxy with a given a metallicity. The shaded regions show the 1σ uncertainty. For comparison, the GRB production efficiency is displayed. The production of SLSN progenitors must be stifled in galaxies with a metallicity above $12 + \log O/H = 8.31^{+0.16}_{-0.30}$, 0.3 dex lower than for GRBs, indicating that SLSN progenitors are on average less metal-enriched than GRBs.

5.3 On the factors behind forming H-poor SLSNe

In the first paper of our series ([Leloudas et al. 2015c](#)), we showed that the metallicities (directly measured from spectra) of SLSN-I hosts were low (median value of $0.27 Z_{\odot}$). They were modestly lower than those of GRB hosts, although the difference was statistically not significant. What is even more striking in the case for SLSNe-I, is that their host spectra exhibit emission lines with very large rest-frame

equivalent widths. In $\approx 50\%$ of the cases, we observed rest-frame equivalent widths exceeding 100 \AA and in some extreme cases reaching up to $500\text{--}800 \text{ \AA}$.

The presence of EELGs in our sample is extremely unusual (only 1% of galaxies in the zCOSMOS survey have rest-frame $EW > 100 \text{ \AA}$; [Amorín et al. 2015](#)), and we determined that their frequency could not be a chance coincidence ($p_{\text{ch}} \sim 10^{-12}$; [Leloudas et al. 2015c](#)). Even GRB hosts do not show, on average, such strong emission lines. The difference to the distribution of a complete sample of GRBs at $z < 1$ ([Hjorth et al. 2012](#)) was found to be statistically significant, although the strongest emitters in our sample were mostly found at $z < 0.3$. The difference was even more pronounced in $[O \text{ III}]\lambda 5007$ than in $H\alpha$, pointing to a higher ionisation fraction in the gas around SLSNe.

These extreme properties were also seen by directly measuring the ionisation parameter q and the ratio between $[N \text{ II}]/H\beta$ and $[O \text{ III}]\lambda 5007/H\alpha$ (BPT diagram; [Baldwin et al. 1981](#)), where the overwhelming majority of H-poor SLSNe were found to be in regions with $\log [O \text{ III}]/H\beta > 0.5$. As the EWs of the lines decrease with time after a starburst (e.g., [Leitherer et al. 1999](#)), showing also a dependence on metallicity ([Inoue 2011](#)) and the shape of the star-formation histories (e.g., [Terlevich et al. 2004](#); [Lee et al. 2009](#)), this evidence strongly points towards very young environments for H-poor SLSN hosts. This led us to propose that the progenitors of H-poor SLSNe are very young, and are on average more short-lived than those of GRBs ([Leloudas et al. 2015c](#)). Although absolute ages are notoriously difficult to determine, we identified a very young stellar population with an age of only $\sim 3 \text{ Myr}$ at the explosion site of PTF12dam, which is the most extreme example in our sample (in terms of emission line strength; [Thöne et al. 2015](#)).

Recently, [Chen et al. \(2016\)](#) questioned the importance of young age for H-poor SLSN progenitors, proposing that metallicity is the only key factor leading to the production

of SLSNe. These authors approximated the effect of age through the sSFR and by comparing the parameter spaces of their SLSN host samples in the metallicity-sSFR plane to complete samples of star-forming galaxies in the *local volume* (11HUGS and LVL; Kennicutt et al. 2008; Lee et al. 2011). However, the two properties are intimately connected through the mass-metallicity-SFR fundamental plane (Manucci et al. 2011) and can therefore not be easily disentangled. Thus we expect to see metallicity and age to drive the SLSN production. Attributing simply the dependence of H-poor SLSNe on metallicity has led many authors (e.g., Lunnan et al. 2014; Chen et al. 2016) to support a magnetar origin for these explosions, although this explanation is of course not unique. Acknowledging that young age plays an important role as well allows models based on more massive progenitors to remain equally competitive (Leloudas et al. 2015c; Thöne et al. 2015).

In contrast to Leloudas et al. (2015c), Perley et al. (2016b) argued that the fraction of starbursts (defined as $\text{sSFR} > 10^{-8} \text{ yr}^{-1}$ in their paper) among SLSN-I hosts is not exceptionally large and that the starburst fraction among H-poor SLSN hosts may be explained by the fact that dwarf galaxies tend to have bursty star-formation histories (e.g. Guo et al. 2016). By using the study of Lee et al. (2009), we show that the fraction of SLSNe-I occurring in EELGs in the Leloudas et al. (2015c) sample is significantly increased even with respect to dwarf galaxies. Lee et al. (2009) determined the fraction of starbursts among local dwarfs in the 11HUGS survey, which is the same survey that Perley et al. (2016b) and Chen et al. (2016) used as their main comparison galaxy sample. Furthermore, Lee et al. (2009) used the same operational definition of starburst that we use for EELGs ($\text{EW}_{\text{rest}} > 100 \text{ \AA}$), making a direct comparison straightforward. They determined that only 6% of dwarf galaxies in the absolute magnitude range of interest ($-19 < M_B < -15$) have $\text{EW}_{\text{rest}} > 100 \text{ \AA}$ (and only 8% have $\text{EW}_{\text{rest}} > 80 \text{ \AA}$). This means that the probability of attaining the same fraction of EELGs among H-poor SLSN hosts as in Leloudas et al. (2015c) is $p_{\text{ch}} < 10^{-6}$. This might be smaller than what is obtained by comparing with zCOSMOS ($p_{\text{ch}} \sim 10^{-12}$) but a chance coincidence is still extremely unlikely. This can also be understood in the following way: if the duty cycles in the bursty SFH of dwarf galaxies are 1–2 Gyr, it is very unlikely that we would happen to catch them by chance so close to an initial starburst when selecting them through a H-poor SLSN.

We therefore argue that *both* low metallicity *and* young age play important roles in the formation of H-poor SLSNe and that stellar evolution in metal-poor, starburst environments needs to be better understood to fully appreciate the context. Especially mass loss in these extreme regimes is poorly understood and more effort needs to be put to understand why these explosions are H-poor and whether this can be attributed to eruptive mass loss (Woosley et al. 2007; Quataert & Shiode 2012), homogeneous evolution (Yoon & Langer 2005), binarity (Eldridge et al. 2008) or another, yet unknown, factor.

5.4 SLSN host galaxies in the context of other galaxy populations

In the previous sections, we discussed particular aspects of the host populations. In the following, we contrast the host properties to those of other galaxy samples.

5.4.1 SLSN-I SLSN host population

Hydrogen-poor SLSNe are preferentially found in blue low-mass dwarf galaxies with high sSFR and average metallicities of $< 0.4 Z_{\odot}$. These properties are similar but somewhat more extreme than of GRB host galaxies. Given these similarities, it has been a long-standing debate how similar the two populations in fact are (e.g., Lunnan et al. 2014; Chen et al. 2015; Leloudas et al. 2015c; Angus et al. 2016; Japelj et al. 2016).

To shed new light on their relationship, we define subsamples of SLSN-I and GRB host galaxies at $z < 1$. Those samples are a factor of a few larger (in total 41 SLSN-I and 52 GRB hosts) than in previous studies and the SEDs of all objects were modelled with the same assumptions and the same software.¹⁴ We quantify the differences with a two-sided AD test, following the method outlined in Sect. 3.4 that includes resampling of the distribution functions, and ensures that the redshift distributions are statistically similar. We reject the null hypothesis that both distributions are statistically similar if the chance probability is $p_{\text{ch}} > 10^{-2}$.

Figures D2 and D3 summarise the results of the statistical tests. The chance probabilities of the M_B , SFR and sSFR distributions remain unchanged between $z < 0.5$ and $0.5 < z < 1.0$. However, the sample sizes significantly differ between both redshift intervals. Using the redshift interval $0.3 < z < 1.0$, which maximises the sample sizes while keeping the look-back time interval comparable to the previous two samples, the chance probability between the distributions of the B -band luminosity, stellar mass, SFR and sSFR is only between 0.04 and 1% (equivalent to $2.6\text{--}3.8\sigma$; Figs. D2, D3). This illustrates that GRB and SLSN host galaxies are similar but yet different. H-poor SLSNe are preferentially found in more extreme environments.

The SLSN-I host population is also similar to EELGS but they are not as extreme as zCOSMOS-EELGs (Figs. D2–D4). These peculiarities are even more pronounced in the stellar-mass-sSFR plane (Fig. 12). At all redshifts the SLSN-I host population is located in the sparsely populated region of low-mass galaxies with high specific SFRs that is separated by ~ 0.5 dex from the main sequence of star-forming galaxies (Whitaker et al. 2014; Lee et al. 2015), exactly where the EELGs lie. Leloudas et al. (2015c) showed that these similarities also extend to spectroscopic properties. This suggests that a fraction of the photometric-only sample should be genuine EELGs as well. A number of hosts are less offset from the galaxy main sequence than

¹⁴ The samples include hosts irrespective of the sampling of the SEDs. For instance, about 30% of our SLSN host sample at $z < 1$ are too faint to obtain meaningful K_s -band constraints even with the most efficient instruments (Sect. 4.3.2) and to a lesser degree in J band. Requiring NIR observations, as done by Japelj et al. (2016), leads to non-random sampling of distribution functions and hence systematic errors.

the bulk of the H-poor population. This necessarily does not contradict this interpretation. Here we discuss the average integrated host properties. [Sánchez Almeida et al. \(2015\)](#) and [Zanella et al. \(2015\)](#) reported that star-forming galaxies can have massive clumps of pristine gas, fed from the IGM, where a localised starburst is triggered.

5.4.2 SLSN-II_h host population

The host population of SLSNe-II_h is characterised by a complex diversity: *i*) the mass and luminosity distributions have dispersions that are a factor 1.5–2 larger compared to any other class of star-forming galaxies; *ii*) the $R - K_s$ has a mean and a dispersion that is similar to star-forming galaxies; and *iii*) the sSFRs are on average a factor of 10 larger than of ordinary star-forming galaxies. Most remarkable is the combination of the large dispersion in mass and luminosity, while the $R - K_s$ colour has a typical mean and dispersion to ordinary star-forming galaxies and the sSFR is even a factor of 10 larger than of normal star-forming galaxies. In the mass-sSFR plane (Fig. 12), the SLSN-II_h host population is shifted by 0.6 dex towards higher sSFR with respect to the main sequence of star-forming galaxies.

Despite the distributions show very large dispersions, the number of hosts with stellar masses of more than $10^{10} M_\odot$ are still scarce. Given the similarity to the mass distribution of GRB host galaxies (Fig. D2), this suggests a stifled production efficiency at metallicities higher than $Z \sim 0.8 Z_\odot$, though with large uncertainties due to the small sample size.

The large dispersion measurements are difficult to reconcile with a single channel scenario like for SLSNe-I and GRBs (Fig. D2). Type II_h SNe are powered by the interaction of the SN ejecta with the circum-stellar material expelled prior to explosion. If the interaction is strong, the signature of the original SN gets washed out, i.e., different types of CCSNe as well as thermonuclear Type Ia SNe can give rise to Type II_h SNe (e.g. [Leloudas et al. 2015a](#)). The fact that all hosts show evidence for recent star-formation and do have very high sSFRs suggests a contamination by Type Ia SNe to be low. This diversity is likely connected with different types of massive stars whose ejecta has strong interaction with the circum-stellar material (see also [Angus et al. 2016](#)).

Intriguingly, the SLSN-II_h sample in [Perley et al. \(2016b\)](#) includes several examples of galaxies with low sSFRs (light red data points in Fig. 12). Their parameter is more similar to that of ordinary core-collapse SNe. This broadens the distribution of the world sample even more and further relaxes the constraints on the environment.

5.4.3 SLSN-II_l host population

The family of type II SLSNe is the rarest class among SLSNe. Only 3 events among the 29 H-rich SLSNe known today belong to this class.¹⁵ Although the SLSN-II sample is very small, the host properties seem to be distinct from the

average properties of the SLSN-II_h family. Type II SLSNe occupy the lower to bottom half of the distribution functions. Two of three hosts are among the least massive galaxies in our sample (10^6 – $10^7 M_\odot$). Those masses are comparable to the least massive dwarf galaxies in the local Universe. Using the parameterisation of the mass-metallicity relation in [Andrews & Martini \(2013\)](#), their masses point to galaxies with a metallicity of $\lesssim 0.3 Z_\odot$, similar to H-poor SLSNe. Such extreme environments are in fact more comparable to that of H-poor SLSNe, as illustrated in the mass-sSFR plane (Fig. 12; see also [Inserra et al. 2016](#)).

Recently, [Yan et al. \(2015\)](#) showed that spectra of H-poor SLSNe can display episodic hydrogen emission. These authors attributed this feature to pulsational instabilities where a progenitor star loses part of its outer envelope. It is hence possibly that SLSNe-II are closely connected SLSNe-I. However, the spectroscopic and photometric properties of SN2013hx showed similarities to brighter ordinary Type II SNe ([Inserra et al. 2016](#)), though even these brighter ordinary Type II SNe are still significantly less luminous than SLSNe. Ad hoc it is not clear how stars with an extended hydrogen envelope could produce such high luminosities. Larger samples are needed to better understand the peculiarities of the SLSN II population.

5.5 Selection biases

Our conclusions could be affected by various selection biases, such as publication bias, target selection bias and classification bias. Moreover, the SUSHIES sample is compiled from different SN surveys, which makes it even more difficult to quantify the effective bias. Our sample comprises of a number of objects from the PS1 and PTF surveys. For these surveys, [Lunnan et al. \(2014\)](#) and [Perley et al. \(2016b\)](#) concluded that a dust bias cannot be excluded but it is expected to be small.

To quantify whether our sample has the same level of bias as the PS1 and PTF samples, we perform two-sided AD tests between the distributions of the host properties. If the probability to randomly drawing a distribution from the PS1/PTF sample that is at least as extreme as the SUSHIES sample is larger than 1% we reject the hypothesis that the level of bias in SUSHIES is different from the PS1 and PTF sample. For a fair comparison we remove common objects and split our sample into two redshift intervals to take the redshift domains of the PS1 and the PTF samples into account: $z < 0.5$ for the PTF sample and $z > 0.5$ for the PS1 sample. The AD tests between the B -band luminosity, mass and SFR distributions of 20 SLSN-I hosts from our sample and 16 SLSN-I hosts from the PTF sample gives a high chance probability of $> 19\%$. For SLSN-II/II_h hosts the probability is with $> 27\%$ even higher (SUSHIES: 13 objects, PTF: 14 objects). A similar result can be obtained for the comparison with the PS1 sample ($p_{\text{ch}} > 8\%$; SUSHIES: 11 objects, PS1: 15 objects). In conclusion, the heterogeneous SUSHIES sample has a similar effective bias like the PS1 and the PTF sample.

The most important finding of current SLSN host studies is the dearth of massive and dust enshrouded hosts. Future NIR satellite missions like *Euclid* and *Wide-Field Infrared Survey Telescope (WFIRST)*, and deep optical/NIR transient surveys like the Subaru/Hyper Suprime-Cam tran-

¹⁵ This number was compiled from the sample presented here and in [Perley et al. \(2016b\)](#), as well as two H-rich SLSNe that were reported in the literature but not discussed in these papers.

sient survey and the Dark Energy Survey could be transformative for SLSN studies (Tanaka et al. 2012, 2013). If these surveys reveal the existence of a population of SLSNe in dusty environments, it could relax the metallicity bias and allow different progenitor channels to explain these energetic explosions, such as the coalescence of two massive stars (Fryer & Woosley 1998; Fryer & Heger 2005; Izzard et al. 2004; Detmers et al. 2008).

6 SUMMARY

We present the photometric properties of 53 H-poor and 16 H-rich SLSNe, detected before 2015 and publicly announced before mid 2015. Among those are four new SLSNe (two of each type), found in the ASIAGO SN catalogue, with a peak luminosity significantly brighter than $M_V = -21$ mag. Each host is a target of deep imaging campaigns, that probes the rest-frame UV to NIR. In addition, we incorporate radio data from wide-field surveys and JVLA observations to put limits on the total star-formation activity. By modelling the spectral energy distributions, we derive physical properties, such as mass, SFR and luminosity, and build distribution functions to ascertain the influence of these properties on the SLSN population. Our main conclusions are:

(i) H-poor SLSNe are preferentially found in very blue low-mass dwarf galaxies. Their sSFRs are on average 0.5 dex larger compared to the main sequence of star-forming galaxies and they populate a part of the sSFR-mass parameter space that is typically occupied by EELGs.

(ii) The host population of SLSNe-II_n shows very complex properties: *i*) the mass and luminosity distributions have dispersions that are a factor 1.5–2 larger compared to all comparison samples; *ii*) the $R - K_s$ has a mean and a dispersion that is similar to star-forming galaxies; and *iii*) the sSFRs are on average a factor of 10 larger than of ordinary star-forming galaxies. These properties argue for a massive star origin of all SLSNe-II_n in our sample but to a low dependency on integrated host properties. Because the luminosity of SLSNe-II_n is determined by the strength of the interaction but not by a particular type of stellar explosion, this diversity suggests multiple progenitor channels.

(iii) The hosts of the three Type II SLSNe are at the bottom of any distribution function. Two out of three Type II SLSNe exploded in the least massive host galaxies in our sample (10^6 – $10^7 M_\odot$). Their hosts are similar to those of H-poor SLSNe. Their strong preference for low-mass and hence low-metallicity galaxies hints to different progenitors from Type II_n SLSNe.

(iv) The scarcity of hosts above $10^{10} M_\odot$ for SLSNe-I and SLSNe-II_n can be attributed to a metallicity bias above which the production efficiency is stifled. Assuming an exponential cut-off, the best-fit cut-off metallicity of H-poor SLSNe at $z < 1$ is $12 + \log \text{O}/\text{H} = 8.31^{+0.16}_{-0.31}$ ($Z \sim 0.4 Z_\odot$), which is 0.4 dex lower than for GRBs. The similarities of the mass distributions of SLSN-II_n and GRB host galaxies suggests a metallicity cut-off at ~ 0.8 solar metallicity.

(v) A growing population of SLSN hosts have masses between 10^6 and $10^7 M_\odot$. Those objects are among the least massive star-forming galaxies known to date and could represent environments similar to those of starburst galaxies in the early Universe.

(vi) The redshift evolution of the SLSN-I host population is consistent with the general cosmic evolution of star-forming galaxies. After detrending the data, the galaxy mass shows evidence for differential evolution at 3.8σ confidence, while differential evolution in the B -band and FUV luminosity can be excluded at 3σ confidence. The evolution of the mass distribution of SLSN-I hosts is similar to the evolution of the mass-metallicity relation, supporting identifying the dearth of massive hosts as due to a metallicity bias.

(vii) GRBs and SLSN-I hosts are similar in many ways. They are both, bluer, more star-forming, and of lower stellar mass than expected from SFR weighted luminosity and mass function. However, there is substantial evidence that SLSNe-I are preferentially found in less massive (and therefore more metal-poor) hosts than GRBs. To conclusively show that they are similar, yet different, large samples with well sampled SEDs are needed.

(viii) SLSN-I hosts and EELGs show similarities even in broad-band properties. This suggests that environmental conditions in EELGs play a very important role in the formation of SLSNe-I. We conclude that metallicity is *not* the sole ingredient regulating the SLSN-I production and suggest that young age plays an important role in the formation of H-poor SLSNe as well.

(ix) The class of H-poor SLSN comprises of fast- and slow-declining SLSNe. A sub-sample of 21 SLSNe-I have measured decline time scales: 14 fast and 7 slow declining SLSNe-I. We find no differences between both host populations. However, larger samples of SLSN with measured decay time scales are needed to draw a firm conclusion.

(x) No host is detected in wide-field radio surveys. At $z < 0.5$, the 4σ limits on the total SFR are a factor of 20 larger than the SFRs derived from SED modelling, ruling out truly obscured star-formation missed by optical diagnostics. This result is consistent with the lack of high-obscured hosts and SLSNe. The deep radio observation of solar-metallicity host of the H-poor MLS121104 reveal no difference between to the SED-derived SFR.

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APPENDIX A: DATA TABLE

Table A1. List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
CSS100217 [SLSN-II, $z = 0.147$, $E(B - V) = 0.01$ mag]						
2MASS		H	17.17 ± 0.08	...	...	This work
CAHA	Omega2000	J	17.34 ± 0.02	2014-01-10	10×60	This work
CAHA	Omega2000	K_s	16.38 ± 0.02	2014-01-11	10×60	This work
SDSS		u'	18.21 ± 0.01	2003-03-26	...	This work
SDSS		g'	17.88 ± 0.01	2003-03-26	...	This work
SDSS		r'	17.65 ± 0.01	2003-03-26	...	This work
SDSS		i'	17.35 ± 0.01	2003-03-26	...	This work
SDSS		z'	17.34 ± 0.02	2003-03-26	...	This work
<i>Swift</i>	UVOT	$uvw2$	19.57 ± 0.07	2015-03-26/04-11	1506	This work
<i>Swift</i>	UVOT	$uvm2$	19.57 ± 0.09	2015-03-26/04-11	1507	This work
<i>Swift</i>	UVOT	$uvw1$	19.24 ± 0.07	2015-03-26/04-11	1448	This work
CSS121015 [SLSN-II, fast declining, $z = 0.287$, $E(B - V) = 0.07$ mag]						
Magellan	IMACS	g'	24.02 ± 0.06	2013-08-14	4×300	This work
Magellan	IMACS	r'	23.40 ± 0.05	2013-08-14	3×300	This work
Magellan	IMACS	i'	23.24 ± 0.08	2013-08-14	4×300	This work
Magellan	FourStar	J	23.15 ± 0.22	2014-11-05	94×61	This work
VLT	FORS2	g_{High}	23.55 ± 0.44	2013-05-30	12×200	This work
VLT	FORS2	R_{Special}	23.33 ± 0.13	2013-05-30	12×200	This work
VLT	HAWK-I	K_s	22.71 ± 0.29	2013-06-02	10×120	This work
CSS140925 [SLSN-I, $z = 0.460$, $E(B - V) = 0.06$ mag]						
SDSS		u'	23.49 ± 3.09 (> 21.47)	2008-12-04	...	This work
SDSS		g'	22.63 ± 0.23	2008-12-04	...	This work
SDSS		r'	22.01 ± 0.25	2008-12-04	...	This work
SDSS		i'	21.92 ± 0.42	2008-12-04	...	This work
SDSS		z'	> 20.52	2008-12-04	...	This work
DES14S2qri [SLSN-I, $z = 1.500$, $E(B - V) = 0.03$ mag]						
DES/Blanco	DECam	g'	> 25.59	2002-11-10	...	This work
SDSS		u'	26.02 ± 19.56 (> 21.91)	2002-11-10	...	This work
SDSS		g'	27.25 ± 24.03 (> 22.98)	2002-11-10	...	This work
SDSS		r'	> 22.99	2002-11-10	...	This work
SDSS		i'	22.44 ± 1.21 (> 22.25)	2002-11-10	...	This work
SDSS		z'	22.19 ± 1.79 (> 20.84)	2002-11-10	...	This work
UKIDSS/UKIRT	WFCAM	Y	> 20.93	...	...	[1]
UKIDSS/UKIRT	WFCAM	J	> 20.81	...	...	[1]
UKIDSS/UKIRT	WFCAM	H	> 19.99	...	...	[1]
UKIDSS/UKIRT	WFCAM	K_s	> 20.05	...	...	[1]
DES14X2byo [SLSN-I, $z = 0.869$, $E(B - V) = 0.03$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	29.50 ± 10.87 (> 25.99)	...	...	This work
CFHTLS/CFHT	MegaPrime	g'	30.98 ± 22.18 (> 26.70)	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	27.18 ± 1.24 (> 26.05)	...	...	This work
CFHTLS/CFHT	MegaPrime	i'	> 25.65	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	> 25.06	...	...	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
DES14X3taz [SLSN-I, $z = 0.608$, $E(B - V) = 0.02$ mag]						
DES/Blanco	DeCam	g'	26.16 ± 0.39	...	...	[2]
DES/Blanco	DeCam	r'	25.07 ± 0.13	...	...	[2]
DES/Blanco	DeCam	i'	24.95 ± 0.13	...	...	[2]
DES/Blanco	DeCam	z'	25.00 ± 0.18	...	...	[2]
VIRMOS/VLT	VIMOS	B	25.82 ± 0.19	...	...	[3]
VIRMOS/VLT	VIMOS	V	25.47 ± 0.17	...	...	[3]
VIRMOS/VLT	VIMOS	R	25.15 ± 0.18	...	...	[3]
VIRMOS/VLT	VIMOS	I	24.51 ± 0.19	...	...	[3]
iPTF13ajg [SLSN-I, slow declining, $z = 0.740$, $E(B - V) = 0.01$ mag]						
Keck	LRIS	g'	26.80 ± 0.20	2014-07/09	...	[11]
Keck	LRIS	R	> 26.00	2014-07/09	...	[11]
Keck	MOSFIRE	J	> 23.50	2014-06-07	...	[11]
Keck	MOSFIRE	K_s	> 23.10	2014-06-08	...	[11]
LSQ12dlf [SLSN-I, fast declining, $z = 0.255$, $E(B - V) = 0.01$ mag]						
Magellan	IMACS	g'	25.49 ± 0.25	2013-08-14	3×300	This work
Magellan	IMACS	i'	24.73 ± 0.32	2013-08-14	3×300	This work
Magellan	FourStar	J	24.38 ± 0.31	2014-11-05	94×61	This work
NTT	EFOSC2	V	25.04 ± 0.15	2014	...	[4]
VLT	FORS2	R_{special}	24.64 ± 0.11	2013-08-02	4×240	This work
LSQ14an ^a [SLSN-I, $z = 0.163$, $E(B - V) = 0.07$ mag]						
CTIO-4m	MOSAIC-2	B	21.34 ± 0.14	2009-04-01	...	This work
CTIO-4m	MOSAIC-2	V	20.79 ± 0.10	2009-04-02	...	This work
CTIO-4m	MOSAIC-2	R	20.47 ± 0.08	2009-04-02	...	This work
<i>GALEX</i>		FUV	21.72 ± 0.39	...	...	[5]
<i>GALEX</i>		NUV	21.27 ± 0.36	...	...	[5]
Magellan	FourStar	J	20.66 ± 0.06	2016-03-27	23×50	This work
Magellan	FourStar	K_s	20.43 ± 0.10	2016-03-27	5.8×50	This work
<i>Swift</i>	UVOT	$uvw2$	21.78 ± 0.12	2014-07-03	5286	This work
<i>Swift</i>	UVOT	$uvm2$	21.66 ± 0.14	2014-12-07	5262	This work
<i>Swift</i>	UVOT	uvu	21.17 ± 0.14	2016-08-16	8137	This work
Subaru	Suprime-Cam	V	20.69 ± 0.01	2005-05-07	12×300	This work
LSQ14mo ^b [SLSN-I, fast declining, $z = 0.256$, $E(B - V) = 0.06$ mag]						
Magellan	IMACS	g'	24.32 ± 0.06	2015-05-13	7×300	This work
Magellan	IMACS	r'	23.85 ± 0.14	2015-11-08	6×200	This work
Magellan	IMACS	i'	23.50 ± 0.08	2015-05-14	10×200	This work
Magellan	FourStar	J	23.47 ± 0.12	2016-03-27	36×50	This work
Magellan	FourStar	K_s	23.10 ± 0.12	2016-03-27	304×6	This work
LSQ14bdq [SLSN-I, slow declining, $z = 0.345$, $E(B - V) = 0.06$ mag]						
Magellan	PISCO	g'	24.54 ± 0.20	2016-11-02	2700	This work
Magellan	PISCO	r'	25.35 ± 0.23	2016-11-02	2700	This work
Magellan	PISCO	i'	25.51 ± 0.31	2016-11-02	2700	This work
Magellan	PISCO	z'	24.17 ± 0.31	2016-11-02	2700	This work
Magellan	FourStar	J	26.65 ± 1.15 (> 24.86)	2016-03-27	57×61	This work
Magellan	FourStar	K_s	> 23.52	2016-03-27	210×6	This work
LSQ14fxj [SLSN-I, $z = 0.360$, $E(B - V) = 0.03$ mag]						
SDSS		u'	23.01 ± 1.10 (> 21.8)	...	...	This work
SDSS		g'	24.05 ± 1.30 (> 22.9)	...	...	This work
SDSS		r'	23.31 ± 1.08 (> 22.4)	...	...	This work
SDSS		i'	> 22.12	...	...	This work
SDSS		z'	> 20.41	...	...	This work
UKIDSS/UKIRT	WFCAM	H	> 19.99	...	...	[1]
UKIDSS/UKIRT	WFCAM	K	> 20.05	...	...	[1]

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
MLS121104 [SLSN-I, $z = 0.303$, $E(B - V) = 0.15$ mag]						
CAHA	Omega2000	K_s	20.37 ± 0.55	2014-08-10	9×60	This work
Magellan [†]	FourStar	J	20.39 ± 0.10	2013-12-18	...	[6]
Magellan [†]	FourStar	K_s	19.63 ± 0.12	2013-12-18	...	[6]
SDSS		u'	26.62 ± 35.33 (> 21.76)	2005-06-12	...	This work
SDSS		g'	22.04 ± 0.16	2005-06-12	...	This work
SDSS		r'	21.22 ± 0.11	2005-06-12	...	This work
SDSS		i'	21.32 ± 0.16	2005-06-12	...	This work
SDSS		z'	20.58 ± 0.32	2005-06-12	...	This work
PS1-10ky [SLSN-I, fast declining, $z = 0.956$, $E(B - V) = 0.03$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	27.75 ± 2.84 (> 25.71)	...	...	This work
CFHTLS/CFHT	MegaPrime	g'	26.99 ± 0.80 (> 27.37)	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	26.39 ± 0.76 (> 25.81)	...	...	This work
CFHTLS/CFHT	MegaPrime	i'	25.94 ± 0.55	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	> 24.90	...	...	This work
PS1-10pm [SLSN-I, $z = 1.206$, $E(B - V) = 0.02$ mag]						
PanSTARRS [†]		g_{PS1}	> 25.20	...	...	[6]
PanSTARRS [†]		r_{PS1}	> 25.10	...	...	[6]
PanSTARRS [†]		i_{PS1}	> 25.00	...	...	[6]
PanSTARRS [†]		z_{PS1}	> 24.00	...	...	[6]
PanSTARRS [†]		y_{PS1}	> 23.00	...	...	[6]
Gemini-N	GMOS	i'	24.99 ± 0.42	2011-01-30	...	[6]
Gemini-N	GMOS	z'	24.86 ± 0.31	2011-01-30	...	[6]
<i>HST</i> [†]	WFC3	$F606W$	25.38 ± 0.05	2012-12-10	...	[6]
<i>HST</i> [†]	WFC3	$F110W$	24.40 ± 0.08	2013-01-15	...	[6]
PS1-10ahf [SLSN-I, $z = 1.100$, $E(B - V) = 0.03$ mag]						
Magellan	PISCO	g'	26.54 ± 0.25	2016-11-02	2700	This work
Magellan	PISCO	r'	25.96 ± 0.23	2016-11-02	2700	This work
Magellan	PISCO	i'	26.72 ± 0.68 (> 25.79)	2016-11-02	2700	This work
Magellan	PISCO	z'	26.08 ± 0.69 (> 25.13)	2016-11-02	2700	This work
CAHA	Omega2000	z'	24.70 ± 0.96	2014-08-10	60×60	This work
CAHA	Omega2000	K_s	22.80 ± 0.87	2014-08-09	59×60	This work
PS1-10awh [SLSN-I, $z = 0.909$, $E(B - V) = 0.07$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	> 26.29	...	...	This work
CFHTLS/CFHT	MegaPrime	g'	28.64 ± 2.25 (> 26.87)	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	27.22 ± 1.48 (> 25.89)	...	...	This work
CFHTLS/CFHT	MegaPrime	i'	26.20 ± 0.62 (> 25.85)	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	24.75 ± 0.41	...	...	This work
<i>HST</i>	WFC3	$F606W$	27.00 ± 0.20	2013-09-04	...	[6]
PS1-10bj [SLSN-I, fast declining, $z = 0.649$, $E(B - V) = 0.01$ mag]						
PanStarrs [†]		g_{PS1}	24.35 ± 0.08	...	...	[7]
PanStarrs [†]		r_{PS1}	23.98 ± 0.12	...	...	[7]
PanStarrs [†]		i_{PS1}	23.75 ± 0.10	...	...	[7]
PanStarrs [†]		z_{PS1}	22.72 ± 0.05	...	...	[7]
PanStarrs [†]		y_{PS1}	> 21.70	...	...	[7]
Magellan [†]	FourStar	J	> 23.80	...	...	[7]
Magellan [†]	FourStar	K_s	> 22.70	...	...	[7]
MUSYC/ <i>Spitzer</i> [†]	IRAC	$3.6 \mu\text{m}$	23.79 ± 0.16	...	...	[7]
MUSYC/ <i>Spitzer</i> [†]	IRAC	$4.5 \mu\text{m}$	24.00 ± 0.18	...	...	[7]

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
PS1-11ap [SLSN-I, slow declining, $z = 0.524$, $E(B - V) = 0.01$ mag]						
<i>HST</i> [†]		<i>F475W</i>	24.02 ± 0.02	2013-10-09	...	[6]
PanSTARRS [†]		<i>g</i> _{PS1}	24.20 ± 0.15	...	...	[6]
PanSTARRS [†]		<i>r</i> _{PS1}	23.32 ± 0.10	...	...	[6]
PanSTARRS [†]		<i>i</i> _{PS1}	22.86 ± 0.09	...	...	[6]
PanSTARRS [†]		<i>z</i> _{PS1}	23.24 ± 0.13	...	...	[6]
PanSTARRS [†]		<i>y</i> _{PS1}	> 22.50	...	...	[6]
<i>Spitzer</i> [†]	IRAC	3.6 μ m	23.33 ± 0.39	...	...	[6]
<i>Spitzer</i> [†]	IRAC	4.5 μ m	23.38 ± 0.29	...	...	[6]
PS1-11tt [SLSN-I, $z = 1.283$, $E(B - V) = 0.01$ mag]						
<i>HST</i> [†]	WFC3	<i>F606W</i>	25.78 ± 0.08	2012-10-02	...	[6]
<i>HST</i> [†]	WFC3	<i>F110W</i>	25.83 ± 0.05	2013-04-21	...	[6]
PanSTARRS [†]		<i>g</i> _{PS1}	> 24.60	...	...	[6]
PanSTARRS [†]		<i>r</i> _{PS1}	> 24.70	...	...	[6]
PanSTARRS [†]		<i>i</i> _{PS1}	> 24.80	...	...	[6]
PanSTARRS [†]		<i>z</i> _{PS1}	> 24.10	...	...	[6]
PanSTARRS [†]		<i>y</i> _{PS1}	> 23.00	...	...	[6]
PS1-11afv [SLSN-I, $z = 1.407$, $E(B - V) = 0.01$ mag]						
<i>HST</i> [†]	WFC3	<i>F606W</i>	25.26 ± 0.08	2013-04-09	...	[6]
<i>HST</i> [†]	WFC3	<i>F110W</i>	24.65 ± 0.08	2012-11-24	...	[6]
PanSTARRS [†]		<i>g</i> _{PS1}	> 24.90	...	...	[6]
PanSTARRS [†]		<i>r</i> _{PS1}	> 24.80	...	...	[6]
PanSTARRS [†]		<i>i</i> _{PS1}	> 25.10	...	...	[6]
PanSTARRS [†]		<i>z</i> _{PS1}	> 24.90	...	...	[6]
PanSTARRS [†]		<i>y</i> _{PS1}	> 22.80	...	...	[6]
PS1-11aib [SLSN-I, $z = 0.997$, $E(B - V) = 0.04$ mag]						
CFHTLS/CFHT	MegaPrime	<i>u</i> [*]	28.21 ± 4.57 (> 25.65)	...	...	This work
CFHTLS/CFHT	MegaPrime	<i>g</i> [']	28.56 ± 3.90 (> 26.18)	...	...	This work
CFHTLS/CFHT	MegaPrime	<i>r</i> [']	27.15 ± 2.65 (> 25.18)	...	...	This work
CFHTLS/CFHT	MegaPrime	<i>i</i> [']	25.38 ± 0.42	...	...	This work
CFHTLS/CFHT	MegaPrime	<i>z</i> [']	24.58 ± 0.40	...	...
PanSTARRS [†]		<i>g</i> _{PS1}	> 24.20	...	...	[6]
PanSTARRS [†]		<i>r</i> _{PS1}	> 24.40	...	...	[6]
PanSTARRS [†]		<i>i</i> _{PS1}	> 24.70	...	...	[6]
PanSTARRS [†]		<i>z</i> _{PS1}	> 23.90	...	...	[6]
PanSTARRS [†]		<i>y</i> _{PS1}	> 22.20	...	...	[6]
PS1-11bam [SLSN-I, $z = 1.565$, $E(B - V) = 0.02$ mag]						
<i>HST</i>	WFC3	<i>F814W</i>	23.82 ± 0.02	2013-10-11	...	[6]
PanSTARRS [†]		<i>g</i> _{PS1}	23.63 ± 0.13	...	...	[6]
PanSTARRS [†]		<i>r</i> _{PS1}	23.64 ± 0.12	...	...	[6]
PanSTARRS [†]		<i>i</i> _{PS1}	23.78 ± 0.13	...	...	[6]
PanSTARRS [†]		<i>z</i> _{PS1}	23.69 ± 0.14	...	...	[6]
PanSTARRS [†]		<i>y</i> _{PS1}	> 23.40	...	...	[6]

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
PS1-11bdn [SLSN-I, $z = 0.738$, $E(B - V) = 0.02$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	28.43 ± 1.92 (> 26.84)	...	...	This work This work
CFHTLS/CFHT	MegaPrime	g'	26.50 ± 0.24	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	26.31 ± 0.31	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	28.96 ± 13.39 (> 25.23)	...	...	This work This work
CFHTLS/CFHT	MegaPrime	y'	27.66 ± 1.44 (> 26.39)	...	...	This work This work
<i>HST</i> [†]	WFC3	<i>F475W</i>	26.09 ± 0.10	2013-11-13	...	[6]
Magellan [†]		r'	> 25.50	2012-07-19	...	[6]
Magellan [†]		i'	25.40 ± 0.25	2013-10-05	...	[6]
Magellan [†]		z'	> 24.20	2013-01-12	...	[6]
Magellan [†]	FourStar	J	> 24.20	2012-12-04	...	[6]
PS1-12zn [SLSN-I, $z = 0.674$, $E(B - V) = 0.02$ mag]						
COSMOS/ <i>GALEX</i>		<i>FUV</i>	26.99 ± 0.87	...	...	[8]
COSMOS/ <i>GALEX</i>		<i>NUV</i>	24.64 ± 0.14	...	...	[8]
COSMOS/CFHT	MegaPrime	u^*	24.68 ± 0.06	...	...	[8]
COSMOS/Subaru	Suprime-Cam	Bj	24.39 ± 0.05	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$g+$	24.59 ± 0.05	...	...	[8]
COSMOS/Subaru	Suprime-Cam	Vj	24.43 ± 0.05	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$r+$	24.22 ± 0.04	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$i+$	23.84 ± 0.04	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$z+$	23.93 ± 0.08	...	...	[8]
COSMOS/UKIRT	PS1-12zn	J	23.63 ± 0.28	...	...	[8]
COSMOS/CFHT	WIRCAM	K_s	23.12 ± 0.16	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$3.6 \mu\text{m}$	23.03 ± 0.04	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$4.5 \mu\text{m}$	23.38 ± 0.09	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$5.8 \mu\text{m}$	23.43 ± 0.41	...	...	[8]
PS1-12bmy [SLSN-I, $z = 1.566$, $E(B - V) = 0.01$ mag]						
<i>HST</i> [†]	WFC3	<i>F814W</i>	25.01 ± 0.05	2013-09-17	...	[6]
Magellan [†]	LDSS3	g'	25.25 ± 0.10	2013-10-05	...	[6]
Magellan [†]	LDSS3	r'	25.46 ± 0.10	2013-10-04	...	[6]
Magellan [†]	LDSS3	i'	25.10 ± 0.16	2013-10-05	...	[6]
Magellan [†]	LDSS3	z'	24.64 ± 0.40	2013-10-05	...	[6]
Magellan [†]	FourStar	J	24.02 ± 0.21	2013-12-18	...	[6]
Magellan [†]	FourStar	K_s	> 22.00	2013-12-18	...	[6]
PS1-12bqf [SLSN-I, $z = 0.522$, $E(B - V) = 0.02$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	23.23 ± 0.01	...	...	[9]
CFHTLS/CFHT	MegaPrime	g'	22.75 ± 0.01	...	...	[9]
CFHTLS/CFHT	MegaPrime	r'	21.83 ± 0.00	...	...	[9]
CFHTLS/CFHT	MegaPrime	i'	21.53 ± 0.00	...	...	[9]
CFHTLS/CFHT	MegaPrime	z'	21.32 ± 0.01	...	...	[9]
<i>GALEX</i>		<i>FUV</i>	24.29 ± 0.15	...	...	[5]
<i>GALEX</i>		<i>NUV</i>	23.79 ± 0.08	...	...	[5]
<i>Spitzer</i>	IRAC	$3.6 \mu\text{m}$	20.82 ± 0.06	...	...	[6]
<i>Spitzer</i>	IRAC	$4.5 \mu\text{m}$	21.29 ± 0.06	...	...	[6]
VIDEO/VLT	VISTA	z	21.39 ± 0.02	...	...	[10]
VIDEO/VLT	VISTA	y	21.15 ± 0.02	...	...	[10]
VIDEO/VLT	VISTA	J	21.12 ± 0.10	...	...	[10]
VIDEO/VLT	VISTA	H	20.90 ± 0.02	...	...	[10]
VIDEO/VLT	VISTA	K	20.77 ± 0.02	...	...	[10]
VIRMOS/CFHT	CFH-12K	B	23.05 ± 0.03	...	...	[3]
VIRMOS/CFHT	CFH-12K	V	22.43 ± 0.03	...	...	[3]
VIRMOS/CFHT	CFH-12K	R	21.87 ± 0.02	...	...	[3]
VIRMOS/CFHT	CFH-12K	I	21.46 ± 0.02	...	...	[3]

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
PS1-13gt [SLSN-I, $z = 0.884$, $E(B - V) = 0.02$ mag]						
NOT	ALFOSC	r'	25.71 ± 1.88 (> 24.11)	2015-03-13	9×400	This work
PanSTARRS [†]		g_{PS1}	> 24.50	...	...	[6]
PanSTARRS [†]		r_{PS1}	> 24.50	...	...	[6]
PanSTARRS [†]		i_{PS1}	> 24.70	...	...	[6]
PanSTARRS [†]		z_{PS1}	> 24.40	...	...	[6]
PanSTARRS [†]		y_{PS1}	> 22.70	...	...	[6]
PTF09atu [SLSN-I, $z = 0.501$, $E(B - V) = 0.04$ mag]						
<i>HST</i>	WFC3	$F390W$	> 25.47	...	...	[12]
VLT	FORS2	g_{High}	27.04 ± 0.30	2012-06-25	3×460	This work
VLT	FORS2	R_{Special}	26.20 ± 0.24	2012-06-25	3×300	This work
VLT	FORS2	I	26.03 ± 0.40	2012-06-25	6×200	This work
VLT	FORS2	z_{Gunn}	25.69 ± 0.45	2012-06-25	11×120	This work
VLT	HAWK-I	J	26.61 ± 1.97 (> 24.88)	2012-07-16	21×120	This work
VLT	HAWK-I	K_s	> 24.79	2012-06-05	23×120	This work
PTF09cnd [SLSN-I, slow declining, $z = 0.258$, $E(B - V) = 0.02$ mag]						
<i>GALEX</i>		NUV	23.00 ± 0.32	...	...	[5]
CAHA	BUSCA	u'	23.90 ± 0.20	2012-10-07	15×500	This work
CAHA	BUSCA	g'	23.50 ± 0.06	2012-10-07	15×500	This work
CAHA	BUSCA	r'	22.97 ± 0.05	2012-10-07	15×500	This work
CAHA	BUSCA	i'	23.07 ± 0.16	2012-10-07	15×500	This work
CAHA	Omega2000	J	23.18 ± 0.46	2014-08-09	65×60	This work
GTC	OSIRIS	r'	23.06 ± 0.07	2013-05-05	1×120	This work
PTF10heh [SLSN-IIIn, $z = 0.338$, $E(B - V) = 0.02$ mag]						
VLT	FORS2	B_{High}	24.30 ± 0.20	2013-05-30	4×120	This work
VLT	FORS2	V_{High}	23.23 ± 0.08	2013-05-30	4×120	This work
VLT	FORS2	R_{Special}	23.02 ± 0.07	2013-05-30	4×120	This work
VLT	FORS2	I	23.06 ± 0.14	2013-05-30	4×120	This work
VLT	FORS2	z_{Gunn}	22.64 ± 0.20	2013-05-30	5×120	This work
VLT	HAWK-I	K_s	21.89 ± 0.15	2013-06-02	5×120	This work
Magellan	FourStar	J	22.56 ± 0.17	2014-03-24	12×32	This work
Magellan	FourStar	K_s	22.10 ± 0.12	2014-03-24	243×4.4	This work
PTF10hgi [SLSN-I, fast declining, $z = 0.099$, $E(B - V) = 0.07$ mag]						
CAHA	Omega2000	H	21.66 ± 0.32	2015-05-09	60×60	This work
TNG		i'	21.83 ± 0.15	2012-05-28	...	[13]
TNG		z'	21.50 ± 0.15	2012-05-28	...	[13]
VLT	ISAAC	J	21.97 ± 0.06	2013-03-28	4×150	This work
VLT	ISAAC	K_s	21.74 ± 0.17	2013-03-28	5×120	This work
WHT	ACAM	g'	22.58 ± 0.23	2012-05-26	...	[13]
WHT	ACAM	r'	22.13 ± 0.09	2012-05-26	...	[13]
PTF10qaf [SLSN-IIIn, $z = 0.284$, $E(B - V) = 0.07$ mag]						
Magellan	FourStar	J	21.65 ± 0.05	2014-11-05	10×61	This work
Magellan	FourStar	K_s	21.36 ± 0.18	2014-11-05	10×6	This work
SDSS		u'	22.97 ± 0.58	2006-09-16	...	This work
SDSS		g'	22.92 ± 0.15	2006-09-16	...	This work
SDSS		r'	22.30 ± 0.13	2006-09-16	...	This work
SDSS		i'	22.01 ± 0.17	2006-09-16	...	This work
SDSS		z'	> 21.35	2006-09-16	...	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
PTF10vqv [SLSN-I, $z = 0.452$, $E(B - V) = 0.06$ mag]						
CAHA	BUSCA	u'	23.85 ± 1.43 (> 22.45)	2012-10-06	15×500	This work
CAHA	BUSCA	g'	24.01 ± 0.61 (> 23.53)	2012-10-06	15×500	This work
CAHA	BUSCA	r'	23.30 ± 0.34	2012-10-06	15×500	This work
CAHA	BUSCA	i'	22.99 ± 0.76 (> 22.27)	2012-10-06	15×500	This work
Magellan	IMACS	g'	23.88 ± 0.11	2013-08-14	1×300	This work
Magellan	IMACS	r'	23.89 ± 0.15	2013-02-08	6×250	This work
Magellan	IMACS	i'	23.86 ± 0.30	2013-08-14	3×300	This work
Magellan	FourStar	J	23.80 ± 0.22	2013-09-25	42×61	This work
VLT	ISAAC	K_s	24.67 ± 1.12 (> 23.55)	2013-09-25	27×27	This work
PTF11dsf [SLSN-II _{in} , $z = 0.385$, $E(B - V) = 0.01$ mag]						
<i>GALEX</i>		<i>NUV</i>	23.14 ± 0.30	...	...	[5]
CAHA	BUSCA	u'	22.42 ± 0.17	2012-10-06	14×500	This work
CAHA	BUSCA	g'	22.02 ± 0.06	2012-10-06	14×500	This work
CAHA	BUSCA	r'	21.22 ± 0.05	2012-10-06	14×500	This work
CAHA	BUSCA	i'	21.25 ± 0.15	2012-10-06	14×500	This work
CAHA	Omega2000	J	21.88 ± 0.15	2013-07-23	30×60	This work
CAHA	Omega2000	H	21.70 ± 0.24	2015-05-07	45×60	This work
CAHA	Omega2000	K_s	20.95 ± 0.38	2013-07-23	30×60	This work
PTF11rks [SLSN-I, fast declining, $z = 0.190$, $E(B - V) = 0.04$ mag]						
<i>GALEX</i>		<i>NUV</i>	22.66 ± 0.50	...	...	[5]
CAHA	BUSCA	u'	22.08 ± 0.26	2012-10-06	18×300	This work
CAHA	BUSCA	g'	21.34 ± 0.05	2012-10-06	18×300	This work
CAHA	BUSCA	r'	20.69 ± 0.04	2012-10-06	18×300	This work
CAHA	BUSCA	i'	20.50 ± 0.07	2012-10-06	1×30	This work
GTC	OSIRIS	r'	20.62 ± 0.04	2014-08-30	1×30	This work
SDSS		z'	20.32 ± 0.69 (> 19.64)	2009-10-17	...	This work
Magellan	FourStar	J	20.51 ± 0.06	2013-08-14	11×61	This work
CAHA	Omega2000	J	20.40 ± 0.07	2013-07-25	20×60	This work
CAHA	Omega2000	H	20.13 ± 0.09	2013-07-25	20×60	This work
CAHA	Omega2000	K_s	20.35 ± 0.41	2013-07-24	30×60	This work
PTF12dam [SLSN-I, slow declining, $z = 0.107$, $E(B - V) = 0.01$ mag]						
CAHA	Omega2000	Y	19.27 ± 0.06	2014-08-10	30×60	This work
CAHA	Omega2000	J	19.20 ± 0.06	2014-05-14	30×60	This work
CAHA	Omega2000	H	19.33 ± 0.09	2014-05-15	30×60	This work
CAHA	Omega2000	K_s	19.33 ± 0.32	2014-05-14	25×60	This work
<i>GALEX</i>		<i>FUV</i>	20.02 ± 0.19	...	...	[5]
<i>GALEX</i>		<i>NUV</i>	20.06 ± 0.14	...	...	[5]
SDSS		u'	19.68 ± 0.06	2003-02-11	...	This work
SDSS		g'	19.32 ± 0.02	2003-02-11	...	This work
SDSS		r'	19.10 ± 0.02	2003-02-11	...	This work
SDSS		i'	18.74 ± 0.03	2003-02-11	...	This work
SDSS		z'	19.21 ± 0.15	2003-02-11	...	This work
<i>Swift</i>	UVOT	<i>uvm2</i>	20.19 ± 0.14	2014-12-15/17	1166	This work
<i>Swift</i>	UVOT	<i>uvw1</i>	19.83 ± 0.13	2014-12-15/17	1177	This work
SCP06F6 [SLSN-I, fast declining, $z = 1.189$, $E(B - V) = 0.01$ mag]						
<i>HST</i>		<i>F775W</i>	> 27.51	...	...	[14]
<i>HST</i>		<i>F850LP</i>	> 27.22	...	...	[14]
<i>HST</i>	WFC3	<i>F606W</i>	27.88 ± 0.20	...	...	[12]

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SN1999as [SLSN-I, $z = 0.127$, $E(B - V) = 0.03$ mag]						
CAHA	Omega2000	J	19.16 ± 0.09	2014-01-10	15×60	This work
CAHA	Omega2000	K	19.49 ± 0.10	2015-05-08	30×60	This work
CAHA	Omega2000	H	18.71 ± 0.11	2014-01-10	15×60	This work
GALEX		FUV	21.31 ± 0.34			[5]
GALEX		NUV	21.05 ± 0.09			[5]
Magellan	Fourstar	K_s	19.43 ± 0.10	2014-06-26	62×9	This work
SDSS		u'	20.44 ± 0.54	2005-05-10	...	This work
SDSS		g'	19.92 ± 0.06	2005-05-10	...	This work
SDSS		r'	19.51 ± 0.05	2005-05-10	...	This work
SDSS		i'	19.61 ± 0.07	2005-05-10	...	This work
SDSS		z'	19.62 ± 0.29	2005-05-10	...	This work
WISE		$W1$	20.32 ± 0.21	...	...
WISE		$W2$	> 20.53	...	...	[15]
WISE		$W3$	> 17.30	...	...	[15]
WISE		$W4$	> 15.43	...	...	[15]
SN1999bd [SLSN-IIIn, $z = 0.151$, $E(B - V) = 0.03$ mag]						
CAHA	Omega2000	J	18.88 ± 0.02	2014-05-14	59×60	This work
GALEX		NUV	22.31 ± 0.32			[5]
Magellan	IMACS	r'	19.96 ± 0.01	2013-02-08	1×120	This work
Magellan	FourStar	K_s	19.66 ± 0.09	2014-11-05	91×6	This work
Swift	UVOT	$w1$	22.06 ± 0.22	2014-12-16–2016-01-03	7287	This work
SDSS		u'	20.56 ± 0.13	2005-03-10	...	This work
SDSS		g'	20.52 ± 0.05	2005-03-10	...	This work
SDSS		r'	19.95 ± 0.04	2005-03-10	...	This work
SDSS		i'	19.42 ± 0.03	2005-03-10	...	This work
SDSS		z'	19.19 ± 0.10	2005-03-10	...	This work
Subaru	Suprime-Cam	V	20.21 ± 0.07	2007-02-18–21	15×200	This work
WISE		$W1$	19.03 ± 0.09	...	...	[15]
WISE		$W2$	19.56 ± 0.28	...	...	[15]
SN2003ma [SLSN-IIIn, $z = 0.289$, $E(B - V) = 0.31$ mag]						
IRSF	SIRIUS	J	19.78 ± 0.11	...	...	[16]
IRSF	SIRIUS	H	19.86 ± 0.16	...	...	[16]
SuperMACHO/Blanco	MOSAIC Imager	B	20.84 ± 0.06	...	...	[17]
SuperMACHO/Blanco	MOSAIC Imager	I	20.21 ± 0.03	...	...	[17]
SN2005ap [SLSN-I, fast declining, $z = 0.283$, $E(B - V) = 0.01$ mag]						
Coma Cluster/CFHT	CFH12K	B	24.43 ± 0.24	...	...	[18]
Coma Cluster/CFHT	CFH12K	V	23.94 ± 0.24	...	...	[18]
Coma Cluster/CFHT	CFH12K	R	23.66 ± 0.04	...	...	[18]
Coma Cluster/CFHT	CFH12K	I	23.51 ± 0.07	...	...	[18]
HST	WFC3	$F390W$	24.32 ± 0.09	...	...	[12]
HST	WFC3	$F160W$	23.48 ± 0.36	...	...	[12]
Magellan [†]	FourStar	J	23.59 ± 0.07	...	...	[6]
NOT	ALFOSC	r'	23.67 ± 0.18	2013-05-05	3×500	This work
NOT	ALFOSC	i'	23.65 ± 0.21	2013-04-14	5×600	This work
Subaru	Suprime-Cam	R	23.43 ± 0.01	2011-04-01	15×210	This work
VLT	ISAAC	J	22.99 ± 0.41	2013-03-27	13×180	This work
VLT	ISAAC	K_s	25.19 ± 1.80 (> 22.60)	2013-03-27	20×120	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SN2006gy [SLSN-II _n , $z = 0.019$, $E(B - V) = 0.14$ mag]						
2MASS		J	11.76 ± 0.02	...	...	This work
2MASS		H	11.61 ± 0.02	...	...	This work
2MASS		K_s	11.65 ± 0.01	...	...	This work
CAHA	BUSCA	u'	16.36 ± 0.01	2012-10-08	18×300	This work
CAHA	BUSCA	g'	14.27 ± 0.01	2012-10-08	18×300	This work
CAHA	BUSCA	r'	13.38 ± 0.02	2012-10-08	18×300	This work
CAHA	BUSCA	i'	12.85 ± 0.01	2012-10-08	18×300	This work
GALEX		FUV	21.58 ± 0.09	...	...	[5]
GALEX		NUV	19.83 ± 0.02	...	...	[5]
SDSS		u'	16.50 ± 0.01	2003-01-29	...	This work
SDSS		g'	14.30 ± 0.01	2003-01-29	...	This work
SDSS		r'	13.34 ± 0.01	2003-01-29	...	This work
SDSS		i'	12.83 ± 0.01	2003-01-29	...	This work
SDSS		z'	12.52 ± 0.01	2003-01-29	...	This work
SN2006oz [SLSN-I, $z = 0.396$, $E(B - V) = 0.04$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	25.68 ± 0.24	...	...	This work
CFHTLS/CFHT	MegaPrime	g'	25.31 ± 0.08	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	24.64 ± 0.07	...	...	This work
CFHTLS/CFHT	MegaPrime	i'	24.34 ± 0.07	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	24.61 ± 0.26	...	...	This work
GTC	OSIRIS	g'	25.66 ± 0.19	2011-08-26	2×180	This work
GTC	OSIRIS	r'	24.42 ± 0.06	2011-08-26	6×180	This work
GTC	OSIRIS	i'	24.00 ± 0.01	2011-08-26	10×90	This work
VLT	HAWK-I	J	23.70 ± 0.13	2012-06-05	15×120	This work
VLT	HAWK-I	K_s	23.61 ± 0.21	2012-07-03	27×120	This work
SN2006tf [SLSN-II _n , $z = 0.074$, $E(B - V) = 0.02$ mag]						
GALEX		FUV	22.49 ± 0.19	...	...	[5]
GALEX		NUV	22.17 ± 0.06	...	...	[5]
Magellan	IMACS	r'	20.90 ± 0.02	2013-02-08	3×180	This work
Magellan	IMACS	i'	20.85 ± 0.04	2013-02-08	3×180	This work
Magellan	IMACS	z'	20.66 ± 0.11	2013-02-08	1×180	This work
VLT	FORS2	u_{High}	22.35 ± 0.19	2013-05-29	1×150	This work
VLT	FORS2	g_{High}	21.11 ± 0.02	2013-05-29	1×150	This work
VLT	FORS2	R_{Special}	20.85 ± 0.03	2013-05-29	1×150	This work
VLT	FORS2	I	20.86 ± 0.05	2013-05-29	1×150	This work
VLT	FORS2	z_{Gunn}	20.72 ± 0.06	2013-05-29	1×150	This work
VLT	HAWK-I	J	20.61 ± 0.06	2013-06-02	5×120	This work
VLT	HAWK-I	K_s	20.43 ± 0.09	2013-06-02	5×120	This work
SN2007bi [SLSN-I, slow declining, $z = 0.128$, $E(B - V) = 0.02$ mag]						
2.2-m MPG	GROND	g'	23.34 ± 0.26	2015-02-13	7×375	This work
2.2-m MPG	GROND	r'	22.67 ± 0.15	2015-02-13	7×375	This work
2.2-m MPG	GROND	i'	22.71 ± 0.28	2015-02-13	5×375	This work
2.2-m MPG	GROND	z'	22.54 ± 0.19	2015-02-13	6×375	This work
CAHA	Omega2000	H	> 20.96	2015-05-08	45×60	This work
GALEX		NUV	24.48 ± 0.34	...	...	[5]
HST	WFC3	$F336W$	23.83 ± 0.28	...	...	[12]
Magellan	IMACS	z'	22.91 ± 0.35	2013-08-13	2×300	This work
Magellan	FourStar	J	22.87 ± 0.29	2014-03-24	9×69	This work
Magellan	FourStar	K_s	22.61 ± 0.23	2014-03-24	192×9	This work
NOT	ALFOSC	r'	22.48 ± 0.07	2013-04-14	3×400	This work
NOT	ALFOSC	i'	22.49 ± 0.10	2013-04-14	5×600	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SN2007bw [SLSN-II _n , $z = 0.140$, $E(B - V) = 0.04$ mag]						
CAHA	Omega2000	J	18.49 ± 0.03	2013-07-24	15×60	This work
CAHA	Omega2000	H	18.20 ± 0.04	2013-07-24	15×60	This work
CAHA	Omega2000	K_s	18.27 ± 0.07	2013-07-24	15×60	This work
SDSS		u'	20.51 ± 0.24	2002-05-08	...	This work
SDSS		g'	19.20 ± 0.03	2002-05-08	...	This work
SDSS		r'	18.76 ± 0.03	2002-05-08	...	This work
SDSS		i'	18.60 ± 0.03	2002-05-08	...	This work
SDSS		z'	19.07 ± 0.20	2002-05-08	...	This work
SN2008am [SLSN-II _n , $z = 0.233$, $E(B - V) = 0.02$ mag]						
<i>GALEX</i>		<i>FUV</i>	21.60 ± 0.12	...	...	[5]
<i>GALEX</i>		<i>NUV</i>	21.28 ± 0.08	...	...	[5]
SDSS		u'	20.86 ± 0.13	2003-01-28	...	This work
SDSS		g'	20.37 ± 0.04	2003-01-28	...	This work
SDSS		r'	19.97 ± 0.05	2003-01-28	...	This work
SDSS		i'	19.65 ± 0.06	2003-01-28	...	This work
SDSS		z'	19.51 ± 0.22	2003-01-28	...	This work
VLT	ISAAC	J	19.49 ± 0.06	2013-03-23	2×90	This work
CAHA	Omega2000	H	19.38 ± 0.08	2015-05-07	30×60	This work
VLT	ISAAC	K_s	19.39 ± 0.12	2013-03-23	2×90	This work
UKIDSS/UKIRT	WFCAM	Y	19.45 ± 0.06	...	...	[1]
UKIDSS/UKIRT	WFCAM	J	19.44 ± 0.08	...	...	[1]
UKIDSS/UKIRT	WFCAM	K_s	19.56 ± 0.15	...	...	[1]
<i>WISE</i>		<i>W1</i>	19.70 ± 0.15	...	...	[15]
SN2008es [SLSN-II, fast declining, $z = 0.205$, $E(B - V) = 0.01$ mag]						
<i>HST</i>	WFC3	<i>F336W</i>	> 25.32	...		[12]
<i>HST</i>	WFC3	<i>F160W</i>	26.85 ± 0.40	...		[12]
GTC	OSIRIS	g'	26.44 ± 0.27	2013-03-15	1920	This work
Keck	LRIS	B	26.96 ± 0.25	...		[12]
Keck	LRIS	R	25.96 ± 0.20	...		[12]
SN2008fz [SLSN-II _n , $z = 0.133$, $E(B - V) = 0.04$ mag]						
CAHA	BUSCA	u'	23.88 ± 0.84 (> 23.06)	2012-10-04	14×500	This work
CAHA	BUSCA	g'	> 23.83	2012-10-04	14×500	This work
CAHA	BUSCA	r'	25.80 ± 2.21 (> 23.93)	2012-10-04	14×500	This work
CAHA	BUSCA	i'	24.23 ± 0.79 (> 23.47)	2012-10-04	14×500	This work
<i>HST</i>	WFC3	<i>F336W</i>	26.73 ± 0.55	...	...	[12]
<i>HST</i>	WFC3	<i>F160W</i>	25.18 ± 0.06	...	...	[12]
Keck	LRIS	R	25.58 ± 0.19	...	...	[12]
Keck	LRIS	B	26.16 ± 0.22	...	...	[12]
VLT ^c	FORS2	R_{Special}	> 24.38	2013-05-30	12×300	This work
SN2009de [SLSN-I, $z = 0.311$, $E(B - V) = 0.04$ mag]						
SDSS		u'	22.34 ± 1.16 (> 21.96)	2005-06-05	...	This work
SDSS		g'	24.36 ± 2.85 (> 23.21)	2005-06-05	...	This work
SDSS		r'	23.75 ± 2.27 (> 22.62)	2005-06-05	...	This work
SDSS		i'	22.89 ± 1.55 (> 22.16)	2005-06-05	...	This work
SDSS		z'	> 20.80	2005-06-05	...	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SN2009jh [SLSN-I, slow declining, $z = 0.349$, $E(B - V) = 0.01$ mag]						
<i>HST</i>	WFC3	<i>F390W</i>	> 25.92	...	...	[12]
<i>HST</i>	WFC3	<i>F160W</i>	25.30 ± 0.15	...	...	[12]
VLT	FORS2	<i>R_{Special}</i>	25.86 ± 0.13	2013-02-20	6×300	This work
VLT	FORS2	<i>I</i>	> 24.49	2013-03-17	3×200	This work
VLT	FORS2	<i>z_{Gunn}</i>	24.18 ± 0.60	2013-02-20	10×120	This work
VLT	HAWK-I	<i>J</i>	26.50 ± 1.58 (> 25.00)	2012-05-20	15×120	This work
VLT	HAWK-I	<i>K_s</i>	24.93 ± 0.92 (> 24.02)	2012-06-03	27×120	This work
SN2009nm [SLSN-II _n , $z = 0.210$, $E(B - V) = 0.01$ mag]						
SDSS		<i>u'</i>	24.13 ± 2.88 (> 22.86)	2012-12-20	...	This work
SDSS		<i>g'</i>	23.00 ± 0.20	2012-12-20	...	This work
SDSS		<i>r'</i>	21.96 ± 0.11	2012-12-20	...	This work
SDSS		<i>i'</i>	22.12 ± 0.20	2012-12-20	...	This work
SDSS		<i>z'</i>	21.80 ± 1.05 (> 21.36)	2012-12-20	...	This work
SN2010gx [SLSN-I, fast declining, $z = 0.230$, $E(B - V) = 0.03$ mag]						
<i>GALEX</i>		<i>NUV</i>	23.36 ± 0.32	...	...	[5]
Gemini-S	GMOS	<i>g'</i>	23.64 ± 0.04	2012-01-21	18×200	This work
Gemini-S	GMOS	<i>r'</i>	22.93 ± 0.04	2011-05-25	9×200	This work
Gemini-S	GMOS	<i>i'</i>	22.94 ± 0.06	2011-05-25	9×200	This work
Gemini-S	GMOS	<i>z'</i>	23.25 ± 0.20	2011-02-28	9×200	This work
Magellan [†]	FourStar	<i>J</i>	22.92 ± 0.01	2012-12-04	...	[6]
SN2010kd [SLSN-I, $z = 0.101$, $E(B - V) = 0.03$ mag]						
<i>GALEX</i>		<i>NUV</i>	22.84 ± 0.53	...	...	[5]
GTC	Osiris	<i>r'</i>	22.46 ± 0.03	2013-04-02	9×60	This work
NOT	ALFOSC	<i>g'</i>	22.84 ± 0.05	2015-03-13	4×300	This work
NOT	ALFOSC	<i>i'</i>	22.55 ± 0.05	2015-03-13	5×240	This work
<i>Swift</i>	UVOT	<i>uvu</i>	22.91 ± 0.37	2014-11-19–2016-01-26	9529	This work
SN2011cp [SLSN-II _n , $z = 0.380$, $E(B - V) = 0.05$ mag]						
SDSS		<i>u'</i>	22.37 ± 1.17 (> 22.01)	2003-01-25	...	This work
SDSS		<i>g'</i>	22.75 ± 0.28	2003-01-25	...	This work
SDSS		<i>r'</i>	21.26 ± 0.10	2003-01-25	...	This work
SDSS		<i>i'</i>	20.63 ± 0.08	2003-01-25	...	This work
SDSS		<i>z'</i>	20.37 ± 0.30	2003-01-25	...	This work
UKIDSS/UKIRT	WFCAM	<i>Y</i>	20.18 ± 0.10	...	...	[1]
UKIDSS/UKIRT	WFCAM	<i>J</i>	20.01 ± 0.09	...	...	[1]
UKIDSS/UKIRT	WFCAM	<i>H</i>	19.72 ± 0.10	...	...	[1]
UKIDSS/UKIRT	WFCAM	<i>K_s</i>	19.04 ± 0.06	...	...	[1]
<i>WISE</i>		<i>W1</i>	18.67 ± 0.06	...	...	[15]
<i>WISE</i>		<i>W2</i>	18.35 ± 0.08	...	...	[15]
<i>WISE</i>		<i>W3</i>	17.56 ± 0.51	...	...	[15]
<i>WISE</i>		<i>W4</i>	> 15.26	...	...	[15]
SN2011ep [SLSN-I, $z = 0.280$, $E(B - V) = 0.02$ mag]						
<i>GALEX</i>		<i>NUV</i>	22.54 ± 0.41	...	...	[5]
SDSS		<i>u'</i>	22.63 ± 1.41 (> 21.88)	2001-05-18	...	This work
SDSS		<i>g'</i>	22.62 ± 0.23	2001-05-18	...	This work
SDSS		<i>r'</i>	22.75 ± 0.35	2001-05-18	...	This work
SDSS		<i>i'</i>	> 22.23	2001-05-18	...	This work
SDSS		<i>z'</i>	> 20.34	2001-05-18	...	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SN2011ke^d [SLSN-I, fast declining, $z = 0.143$, $E(B - V) = 0.01$ mag]						
VLT	FORS2	u_{High}	22.94 ± 0.08	2013-05-30	1×400	This work
VLT	FORS2	g_{High}	22.49 ± 0.03	2013-05-30	1×300	This work
VLT	FORS2	R_{Special}	22.43 ± 0.04	2013-05-30	1×90	This work
VLT	FORS2	I	22.24 ± 0.06	2013-05-30	1×90	This work
VLT	FORS2	z_{Gunn}	22.66 ± 0.19	2013-05-30	1×90	This work
VLT	HAWK-I	K_s	22.19 ± 0.27	2013-06-02	3×120	This work
SN2011kf [SLSN-I, fast declining, $z = 0.245$, $E(B - V) = 0.02$ mag]						
VLT	FORS2	b_{high}	24.22 ± 0.06	2013-05-30	12×300	This work
VLT	FORS2	R_{special}	23.46 ± 0.08	2013-05-30	1×300	This work
VLT	FORS2	I	23.37 ± 0.14	2013-05-30	12×120	This work
VLT	FORS2	z_{Gunn}	23.45 ± 0.34	2013-05-30	12×120	This work
VLT	HAWK-I	J	24.37 ± 0.44	2013-06-02	22×120	This work
VLT	HAWK-I	K_s	23.95 ± 0.43	2013-06-02	22×120	This work
SN2012il [SLSN-I, fast declining, $z = 0.175$, $E(B - V) = 0.02$ mag]						
<i>GALEX</i>		<i>FUV</i>	22.31 ± 0.40	...	...	[5]
<i>GALEX</i>		<i>NUV</i>	22.78 ± 0.31	...	...	[5]
<i>HST</i>	WFC3	<i>F336W</i>	22.78 ± 0.06	...	...	[12]
Magellan	IMACS	r'	21.62 ± 0.03	20013-11-18	1×180	This work
Magellan [†]	FourStar	J	21.78 ± 0.11	...	...	[6]
Magellan [†]	FourStar	K_s	21.90 ± 0.20	...	...	[6]
SDSS		u'	24.00 ± 3.00	2005-02-04	...	This work
SDSS		g'	21.85 ± 0.09	2005-02-04	...	This work
SDSS		g'	21.85 ± 0.09	2005-02-04	...	This work
SDSS		i'	21.62 ± 0.16	2005-02-04	...	This work
SDSS		z'	22.54 ± 1.87	2013-02-08	1×180	This work
<i>Swift</i> /UVOT		$uvw1$	21.54 ± 0.68 (> 20.92)	2016-01-09	140	This work This work
SN2013dg [SLSN-I, fast declining, $z = 0.265$, $E(B - V) = 0.04$ mag]						
Magellan	IMACS	g'	26.49 ± 0.95 (> 25.53)	2014-06-27	4×300	This work
Magellan	IMACS	r'	25.93 ± 0.67 (> 25.35)	2014-06-27	6×300	This work
Magellan	IMACS	i'	25.21 ± 0.73 (> 24.55)	2014-06-27	5×240	This work
Magellan	FourStar	J	> 23.74	2014-03-23	26×69	This work
SN2013hx [SLSN-IIIn, fast declining, $z = 0.130$, $E(B - V) = 0.02$ mag]						
Magellan	IMACS	g'	24.71 ± 0.45	2016-02-01	2×300	This work
Magellan	IMACS	r'	24.55 ± 0.35	2016-02-01	4×180	This work
Magellan	IMACS	i'	23.54 ± 0.32	2016-02-01	5×240	This work
SN2013hy [SLSN-I, $z = 0.663$, $E(B - V) = 0.03$ mag]						
DES/Blanco	DECam	g'	24.24 ± 0.13	...	...	[19]
DES/Blanco	DECam	r'	23.65 ± 0.10	...	...	[19]
DES/Blanco	DECam	i'	23.31 ± 0.10	...	...	[19]
DES/Blanco	DECam	z'	23.26 ± 0.17	...	...	[19]
SN2015bn [SLSN-I, $z = 0.110$, $E(B - V) = 0.02$ mag]						
<i>GALEX</i>		<i>NUV</i>	23.62 ± 0.59	...	...	[5]
SDSS		u'	24.51 ± 4.05	1999-03-22	...	This work
SDSS		g'	22.42 ± 0.15	1999-03-22	...	This work
SDSS		r'	22.81 ± 0.31	1999-03-22	...	This work
SDSS		i'	21.74 ± 0.21	1999-03-22	...	This work
SDSS		z'	21.09 ± 0.41	1999-03-22	...	This work

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SN1000+0216 [SLSN-I, $z = 3.899$, $E(B - V) = 0.02$ mag]						
COSMOS/Subaru	Suprime-Cam	Bj	26.82 ± 0.24	...	...	[8]
COSMOS/Subaru	Suprime-Cam	Vj	25.65 ± 0.12	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$g+$	26.70 ± 0.26	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$r+$	25.09 ± 0.08	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$i+$	24.60 ± 0.06	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$z+$	24.75 ± 0.16	...	...	[8]
COSMOS/UKIRT	WFCAM	J	24.30 ± 0.37	...	...	[8]
COSMOS/CFHT	WIRCAM	K_s	24.81 ± 0.61	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$3.6 \mu\text{m}$	23.14 ± 0.08	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$4.5 \mu\text{m}$	22.74 ± 0.10	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$5.8 \mu\text{m}$	22.72 ± 0.23	...	...	[8]
COSMOS/ <i>Spitzer</i>	IRAC	$8.5 \mu\text{m}$	21.50 ± 0.28	...	...	[8]
UltraVISTA/VISTA	VIRCAM	Y	24.20 ± 0.05	...	...	[20]
UltraVISTA/VISTA	VIRCAM	J	23.79 ± 0.05	...	...	[20]
UltraVISTA/VISTA	VIRCAM	H	23.58 ± 0.06	...	...	[20]
UltraVISTA/VISTA	VIRCAM	K_s	23.45 ± 0.06	...	...	[20]
SN2213-1745 [SLSN-I, $z = 2.046$, $E(B - V) = 0.02$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	24.35 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	g'	23.97 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	23.87 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	i'	23.78 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	23.67 ± 0.02	...	...	This work
Magellan	FourStar	J	22.76 ± 0.12	2014-11-05	37×61	This work
SNLS06D4eu [SLSN-I, $z = 1.588$, $E(B - V) = 0.02$ mag]						
CFHTLS/CFHT	MegaPrime	u^*	24.55 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	g'	24.19 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	r'	24.11 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	i'	24.01 ± 0.01	...	...	This work
CFHTLS/CFHT	MegaPrime	z'	23.92 ± 0.02	...	...	This work
VLT	HAWK-I	J	23.85 ± 0.26	2013-10-13	6×180	This work
VLT	HAWK-I	K_s	23.74 ± 0.30	2013-10-13	14×120	This work
SNLS07D2bv [SLSN-I, $z \sim 1.5$, $E(B - V) = 0.02$ mag]						
COSMOS/CFHT	MegaPrime	u^*	26.54 ± 0.17	...	...	[8]
COSMOS/Subaru	Suprime-Cam	Bj	26.71 ± 0.22	...	...	[8]
COSMOS/Subaru	Suprime-Cam	Vj	26.42 ± 0.20	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$g+$	26.95 ± 0.27	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$r+$	27.03 ± 0.29	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$i+$	26.33 ± 0.23	...	...	[8]
COSMOS/Subaru	Suprime-Cam	$z+$	26.47 ± 0.69	...	...	[8]
COSMOS/UKIRT	PS1-12zn	J	25.67 ± 1.12	...	...	[8]
COSMOS/CFHT	WIRCAM	K_s	24.66 ± 0.60	...	...	[8]

Table A1 – *continued* List of host observations and their photometries.

Survey/ Telescope	Instrument	Filter	Brightness (mag _{AB})	Date	Exposure time (s)	Reference
SSS120810 [SLSN-I, fast declining, $z = 0.156$, $E(B - V) = 0.02$ mag]						
<i>Swift</i>	UVOT	<i>uvm2</i>	23.02 ± 0.17	2014-11-09–2016-01-28	8922	This work
VLT	FORS2	<i>g</i> _{High}	22.71 ± 0.10	2013-05-30	1×300	This work
VLT	FORS2	<i>R</i> _{Special}	22.61 ± 0.06	2013-05-30	1×300	This work
VLT	FORS2	<i>I</i>	22.47 ± 0.07	2013-05-30	3×120	This work
VLT	FORS2	<i>z</i> _{Gunn}	22.43 ± 0.14	2013-05-30	3×120	This work
VLT	HAWK-I	<i>J</i>	23.11 ± 0.14	2013-06-02	6×120	This work
VLT	HAWK-I	<i>K_s</i>	23.38 ± 0.24	2013-06-02	6×120	This work

Note. — Data were not corrected for Galactic extinction apart from the data designated by [†]. The CFHTLS *y'* band filter is similar to CFHTLS *i'*. If a measurement has a confidence of $< 2\sigma$, we also report the 3σ limiting magnitude. ^a An error of 0.15 mag was added in quadrature to the optical photometry due to the contamination by a bright star.

^b The brightness was measured with a circular aperture with a diameter of $1.5 \times \text{FWHM}$ of the stellar PSF.

^c The object is on Chip 1 and 2. The measurement is only for Chip 2.

^d The brightness was measured with a circular aperture with a diameter of 7 px of the stellar PSF.

References. — [1]: [Lawrence et al. \(2007\)](#); [2]: [Smith et al. \(2016\)](#); [3]: [Le Fèvre et al. \(2004\)](#); [4]: [Nicholl et al. \(2014\)](#); [5]: [Bianchi et al. \(2011\)](#); [6]: [Lunnan et al. \(2014\)](#); [7]: [Lunnan et al. \(2013\)](#); [8]: [Ilbert et al. \(2009\)](#); [9]: [Hudelot et al. \(2012\)](#); [10]: [Jarvis et al. \(2013\)](#); [11]: [Vreeswijk et al. \(2014\)](#); [12]: [Angus et al. \(2016\)](#); [13]: Inserra (priv. comm.); [14]: [Barbary et al. \(2009\)](#); [15]: AllWISE Source Catalog; [16]: [Kato et al. \(2007\)](#); [17]: [Rest et al. \(2011\)](#); [18]: [Adami et al. \(2006\)](#); [19]: [Papadopoulos et al. \(2015\)](#); [20]: [McCracken et al. \(2012\)](#)

Table A2. Radio observations of SLSN host galaxies.

Object	Redshift	Survey/ Telescope	Observed frequency	r.m.s (mJy/beam)	Date	Reference
SLSN-I host galaxies						
CSS140925	0.460	NVSS/VLA	1.4 GHz	0.45	...	[1]
DES14S2qri	1.500	FIRST/VLA	1.4 GHz	0.155	...	[2]
DES14X2byo	0.869	FIRST/VLA	1.4 GHz	0.108	...	[2]
DES14X3taz	0.608	FIRST/VLA	1.4 GHz	0.106	...	[2]
iPTF13ajg [†]	0.740	FIRST/VLA	1.4 GHz	0.102	...	[2]
LSQ12dlf [‡]	0.255	NVSS/VLA	1.4 GHz	0.45	...	[1]
LSQ14an	0.163	NVSS/VLA	1.4 GHz	0.45	...	[1]
LSQ14mo [‡]	0.256	NVSS/VLA	1.4 GHz	0.45	...	[1]
LSQ14bdq [†]	0.345	NVSS/VLA	1.4 GHz	0.45	...	[1]
LSQ14fxj	0.360	FIRST/VLA	1.4 GHz	0.114	...	[2]
MLS121104	0.303	JVLA	1.4 GHz	0.015	2015-07-28 & 2015-08-05	This work This work
PS1-10ky	0.956	FIRST/VLA	1.4 GHz	0.162	...	[2]
PS1-10pm	1.206	FIRST/VLA	1.4 GHz	0.141	...	[2]
PS1-10ahf	1.158	FIRST/VLA	1.4 GHz	0.11	...	[2]
PS1-10awh	0.909	FIRST/VLA	1.4 GHz	0.105	...	[2]
PS1-10bzj [‡]	0.649	NVSS/VLA	1.4 GHz	0.45	...	[1]
PS1-11ap [†]	0.524	FIRST/VLA	1.4 GHz	0.144	...	[2]
PS1-11tt	1.283	FIRST/VLA	1.4 GHz	0.151	...	[2]
PS1-11afv	1.407	FIRST/VLA	1.4 GHz	0.162	...	[2]
PS1-11aib	0.997	FIRST/VLA	1.4 GHz	0.139	...	[2]
PS1-11bam	1.565	FIRST/VLA	1.4 GHz	0.139	...	[2]
PS1-11bdn	0.738	FIRST/VLA	1.4 GHz	0.117	...	[2]
PS1-12zn	0.674	FIRST/VLA	1.4 GHz	0.153	...	[2]
PS1-12bmy	1.566	NVSS/VLA	1.4 GHz	0.45	...	[1]
PS1-12bqf	0.522	FIRST/VLA	1.4 GHz	0.123	...	[2]
PS1-13gt	0.884	FIRST/VLA	1.4 GHz	0.16	...	[2]
PTF09atu	0.501	FIRST/VLA	1.4 GHz	0.172	...	[2]
PTF09cnd [†]	0.258	FIRST/VLA	1.4 GHz	0.141	...	[2]
PTF10hgi [‡]	0.099	NVSS/VLA	1.4 GHz	0.45	...	[1]
PTF10vqv	0.452	FIRST/VLA	1.4 GHz	0.17	...	[2]
PTF11rks [‡]	0.190	NVSS/VLA	1.4 GHz	0.45	...	[1]
PTF12dam [†]	0.107	FIRST/VLA	1.4 GHz	0.14	...	[2]
SCP06F6 [‡]	1.189	FIRST/VLA	1.4 GHz	0.143	...	[2]
SN1999as	0.127	FIRST/VLA	1.4 GHz	0.142	...	[2]
SN2005ap [‡]	0.283	FIRST/VLA	1.4 GHz	0.13	...	[2]
		JVLA	1.4 GHz	0.025	2015-09-20	This work
SN2006oz	0.396	FIRST/VLA	1.4 GHz	0.099	...	[2]
SN2007bi [†]	0.128	FIRST/VLA	1.4 GHz	0.136	...	[2]
SN2009de	0.311	FIRST/VLA	1.4 GHz	0.149	...	[2]
SN2009jh [†]	0.349	FIRST/VLA	1.4 GHz	0.145	...	[2]
SN2010gx [‡]	0.230	NVSS/VLA	1.4 GHz	0.45	...	[1]
SN2010kd	0.101	FIRST/VLA	1.4 GHz	0.159	...	[2]
SN2011ep	0.280	FIRST/VLA	1.4 GHz	0.158	...	[2]
SN2011ke [‡]	0.143	FIRST/VLA	1.4 GHz	0.158	...	[2]
SN2011kf [‡]	0.245	FIRST/VLA	1.4 GHz	0.154	...	[2]
SN2012il [‡]	0.175	FIRST/VLA	1.4 GHz	0.145	...	[2]
SN2013dg [‡]	0.265	FIRST/VLA	1.4 GHz	0.199	...	[2]
SN2013hy	0.663	NVSS/VLA	1.4 GHz	0.45	...	[1]
SN2015bn	0.110	FIRST/VLA	1.4 GHz	0.147	...	[2]
SN1000+0216	3.899	FIRST/VLA	1.4 GHz	0.135	...	[2]
SN2213-1745	2.046	NVSS/VLA	1.4 GHz	0.45	...	[1]
SNLS06D4eu	1.588	NVSS/VLA	1.4 GHz	0.45	...	[1]
SNLS07D2bv	1.500	FIRST/VLA	1.4 GHz	0.143	...	[2]
SSS120810 [‡]	0.156	SUMSS	843 MHz	1.3	...	[3]

Table A2 – *continued* Radio observations of SLSN host galaxies.

Object	Redshift	Survey/ Telescope	Observed frequency	r.m.s (mJy/beam)	Date	Reference
SLSN-II_n host galaxies						
CSS100217	0.147	FIRST/VLA	1.4 GHz	0.15	...	[2]
PTF10heh	0.338	FIRST/VLA	1.4 GHz	0.12	...	[2]
PTF10qaf	0.284	FIRST/VLA	1.4 GHz	0.135	...	[2]
PTF11dsf	0.385	FIRST/VLA	1.4 GHz	0.15	...	[2]
SN1999bd	0.151	FIRST/VLA	1.4 GHz	0.164	...	[2]
SN2003ma	0.289	...	...	...
SN2006gy	0.019	NVSS/VLA	1.4 GHz	0.45	...	[1]
SN2006tf	0.074	FIRST/VLA	1.4 GHz	0.132	...	[2]
SN2007bw	0.14	FIRST/VLA	1.4 GHz	0.162	...	[2]
SN2008am	0.233	FIRST/VLA	1.4 GHz	0.144	...	[2]
SN2008fz	0.133	FIRST/VLA	1.4 GHz	0.14	...	[2]
		JVLA	1.4 GHz	0.015	2015-07-21	This work
SN2009nm	0.21	FIRST/VLA	1.4 GHz	0.141	...	[2]
SN2011cp	0.38	FIRST/VLA	1.4 GHz	0.137	...	[2]
SLSN-II host galaxies						
CSS121015 [‡]	0.287	FIRST/VLA	1.4 GHz	0.172	...	[2]
SN2008es [‡]	0.205	FIRST/VLA	1.4 GHz	0.147	...	[2]
SN2013hx [‡]	0.13	SUMSS	843 MHz	1.3	...	[3]

Note. — Objects with decline time-scales smaller/larger than 50 days are marked by a [†]/_‡.

References. — [1]: Condon et al. (1998); [2]: Becker et al. (1995); [3]: Mauch et al. (2003)

**APPENDIX B: SPECTRAL ENERGY
DISTRIBUTION FITS**

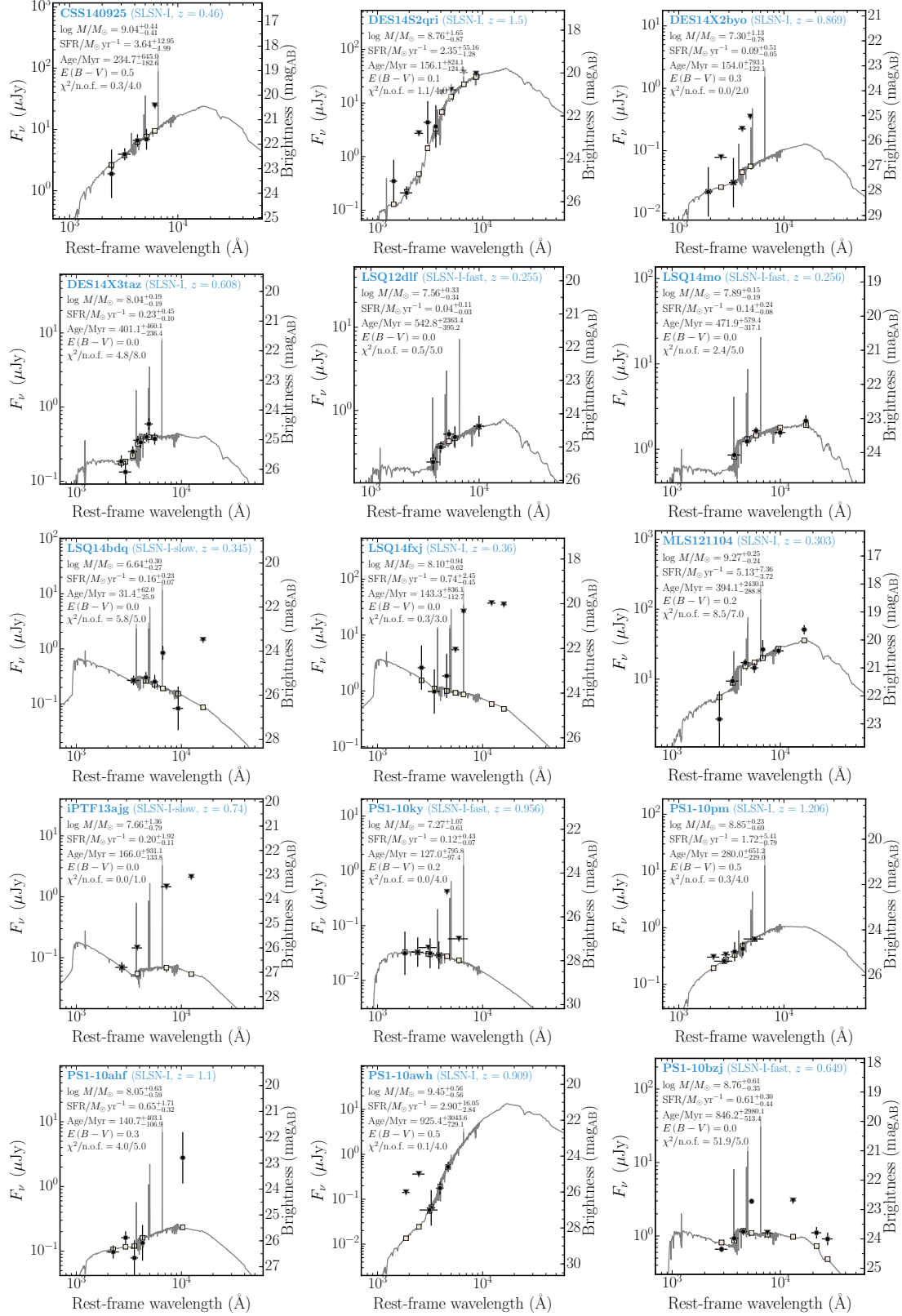


Figure B1. Similar to Fig. 3. Spectral energy distributions of hosts of H-poor SLSNe from 1000 to 40000 Å. The solid line displays the best-fit model of the SED with **Le Phare**. The squares in a lighter shade are the model predicted magnitudes. Key fitting parameters are displayed for each SED. See Table 4 and Sect. 3.3 for details.

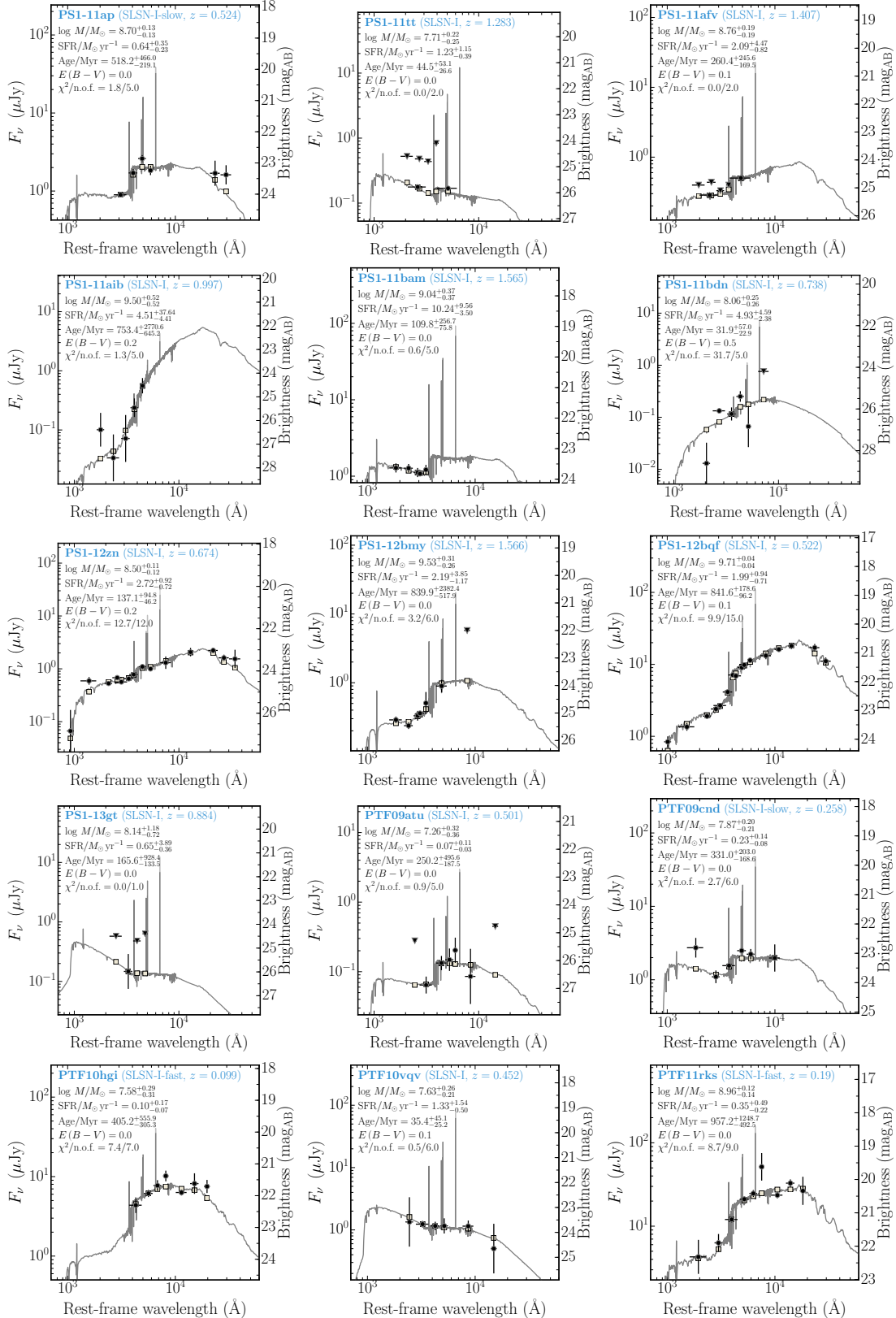


Figure B1. (Continued)

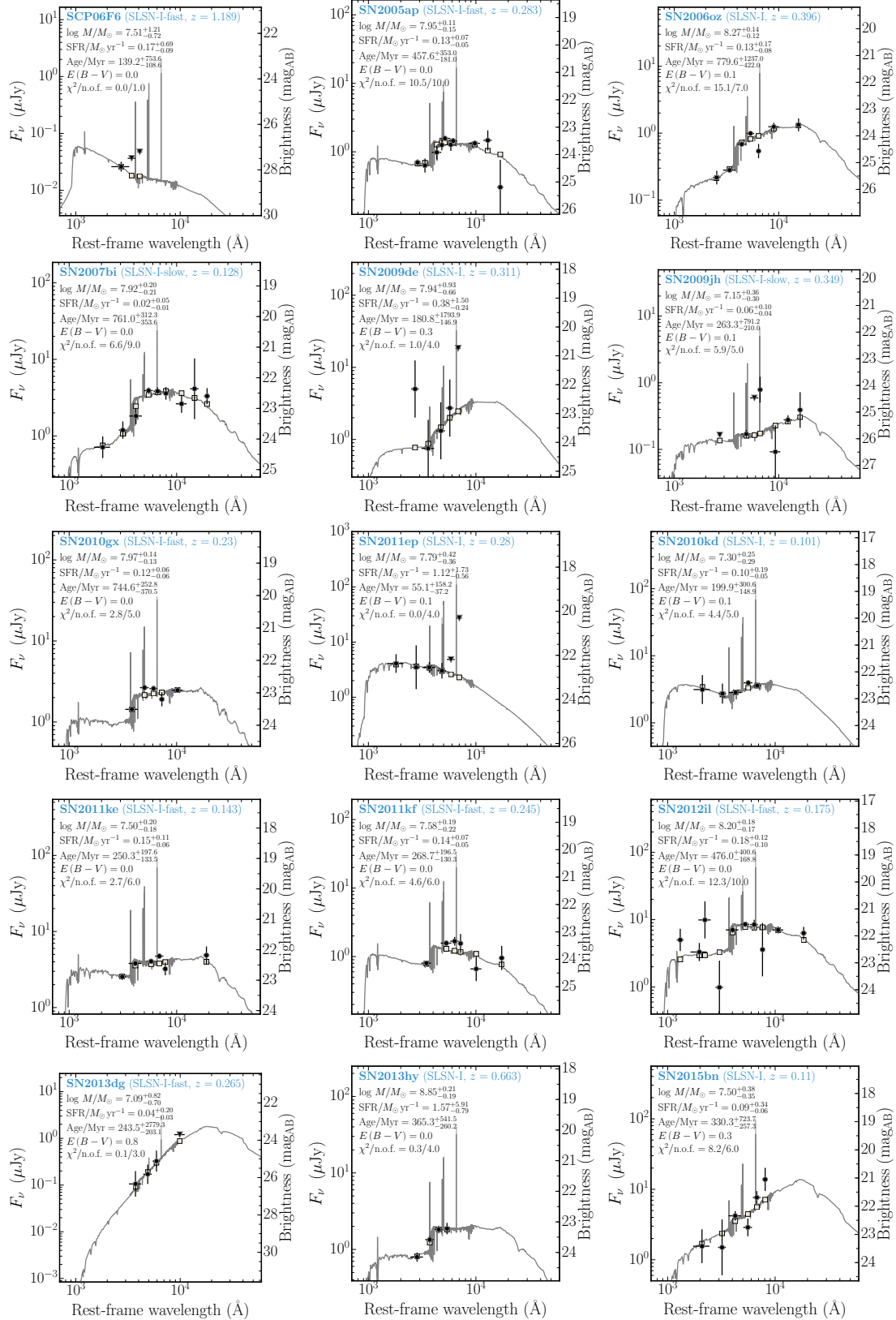
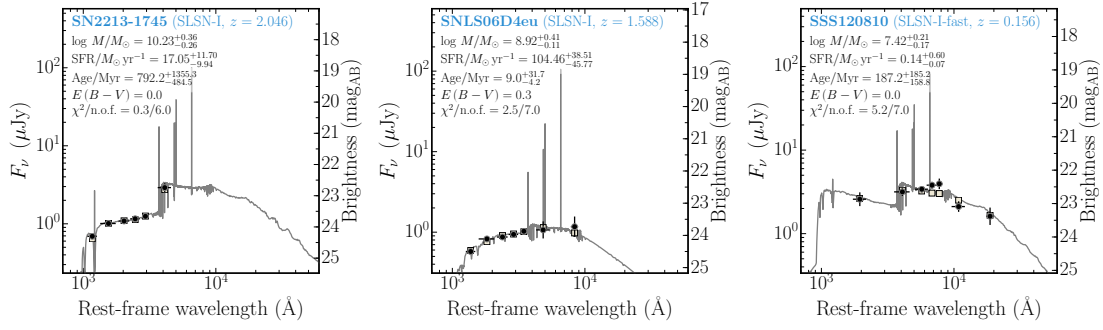


Figure B1. (Continued)

**Figure B1.** (Continued)

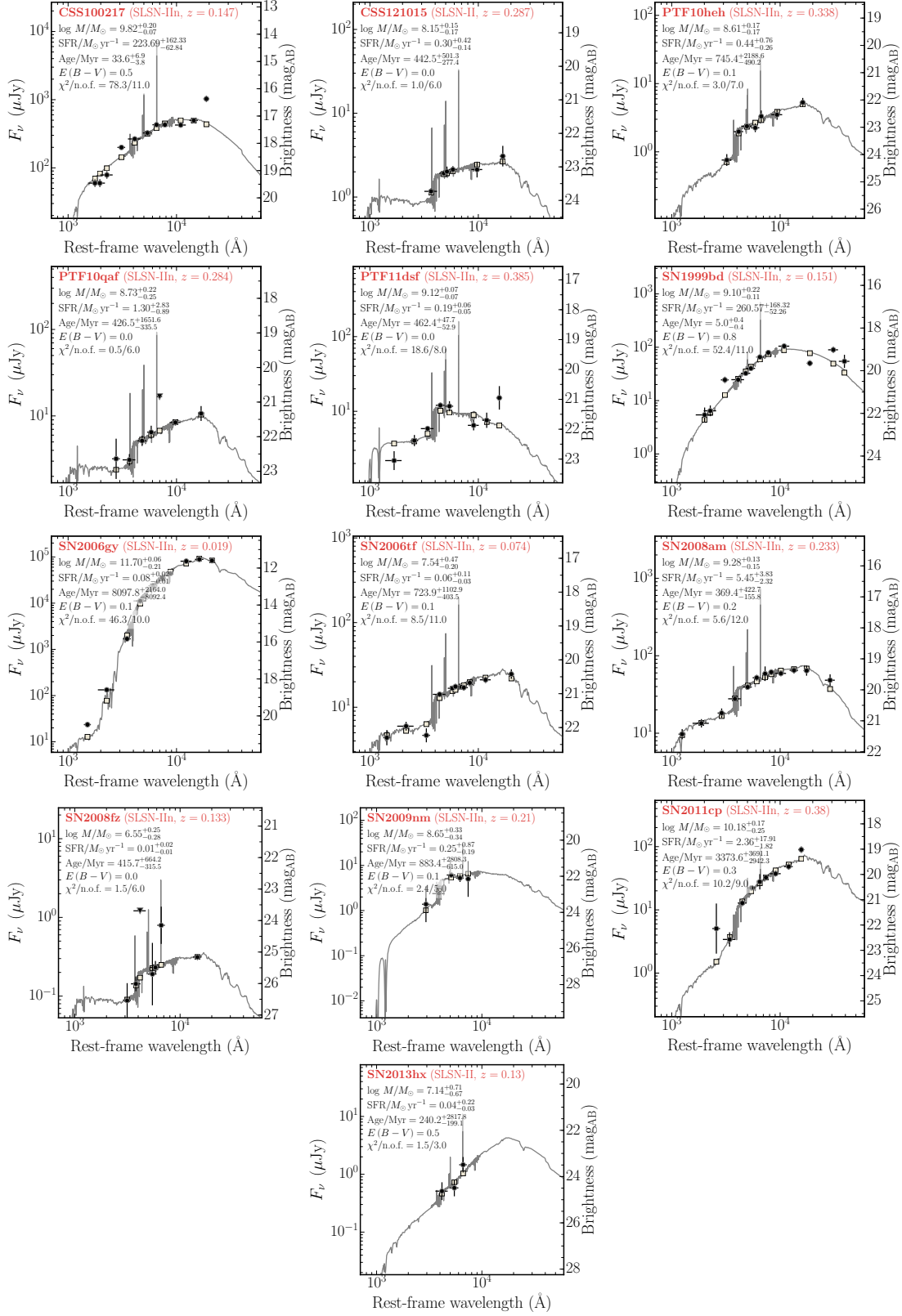


Figure B2. Similar to Figs. 2 and B1 but for H-rich host galaxies.

APPENDIX C: POSTAGE STAMPS

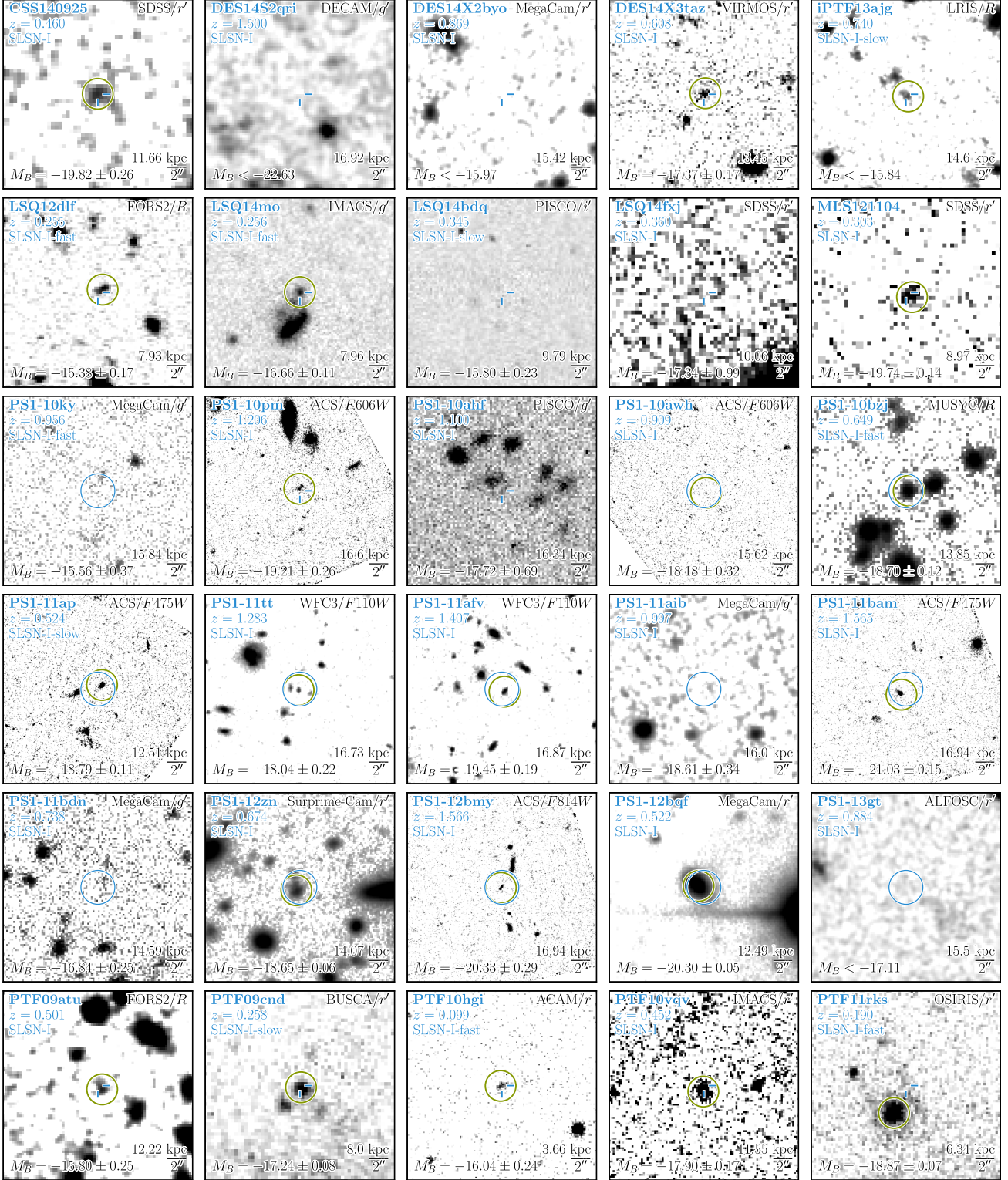


Figure C1. Similar to Fig. 5. Each panel has a size of $20'' \times 20''$ where North is up and East is left. The crosshair marks the position of the SNe after aligning a SN and a host image. If no SN image was available, the blue circle (arbitrary radius) indicates the SN position reported in the literature. The average alignment error was $0''.17$ but it exceeded $1''.0$ in a few cases. See Sect. 4.2 for details. The green circle (arbitrary radius) marks the host galaxy. The observed absolute B -band brightness is displayed in the lower left. The images of CSS140925, DES14S2qri, DES14X2byo, PS1-11aib, PS1-13gt, PTF09atu, SN2008es, SN2013dg, SN2013hx and SN2015bn were smoothed with a Gaussian kernel (width of 1 px) to improve the visibility of the host.

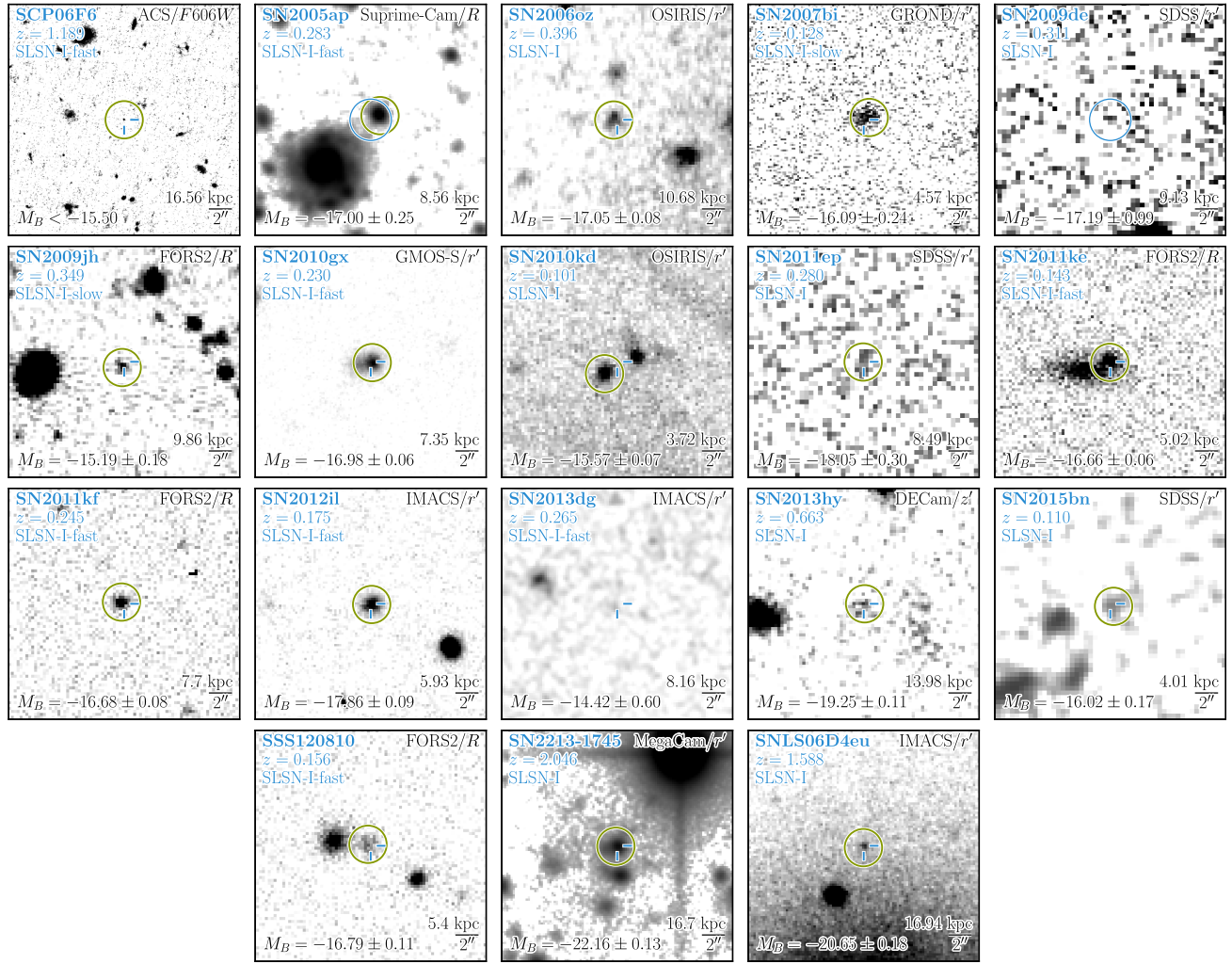


Figure C1. (Continued)

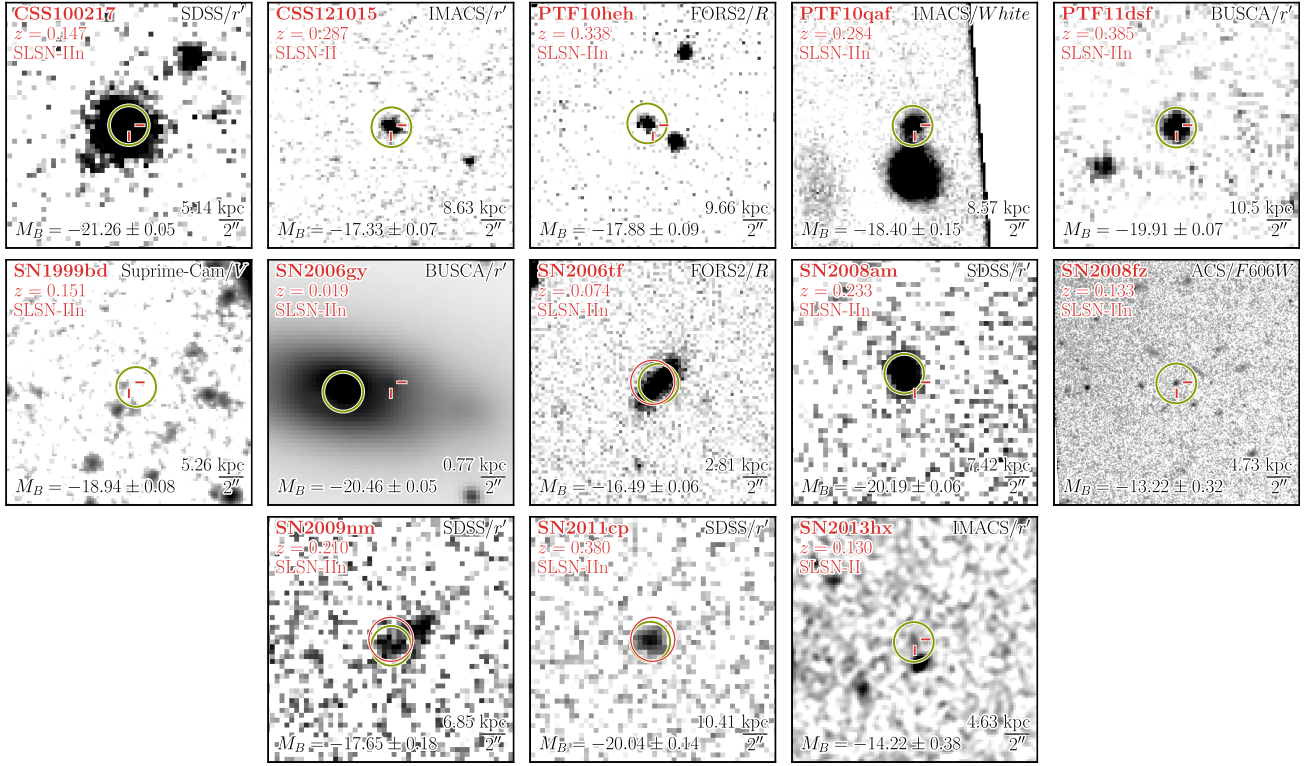


Figure C2. Same as Fig. 5 but for H-rich SLSNe

**APPENDIX D: STATISTICAL PROPERTIES OF
THE COMPARISON SAMPLES**

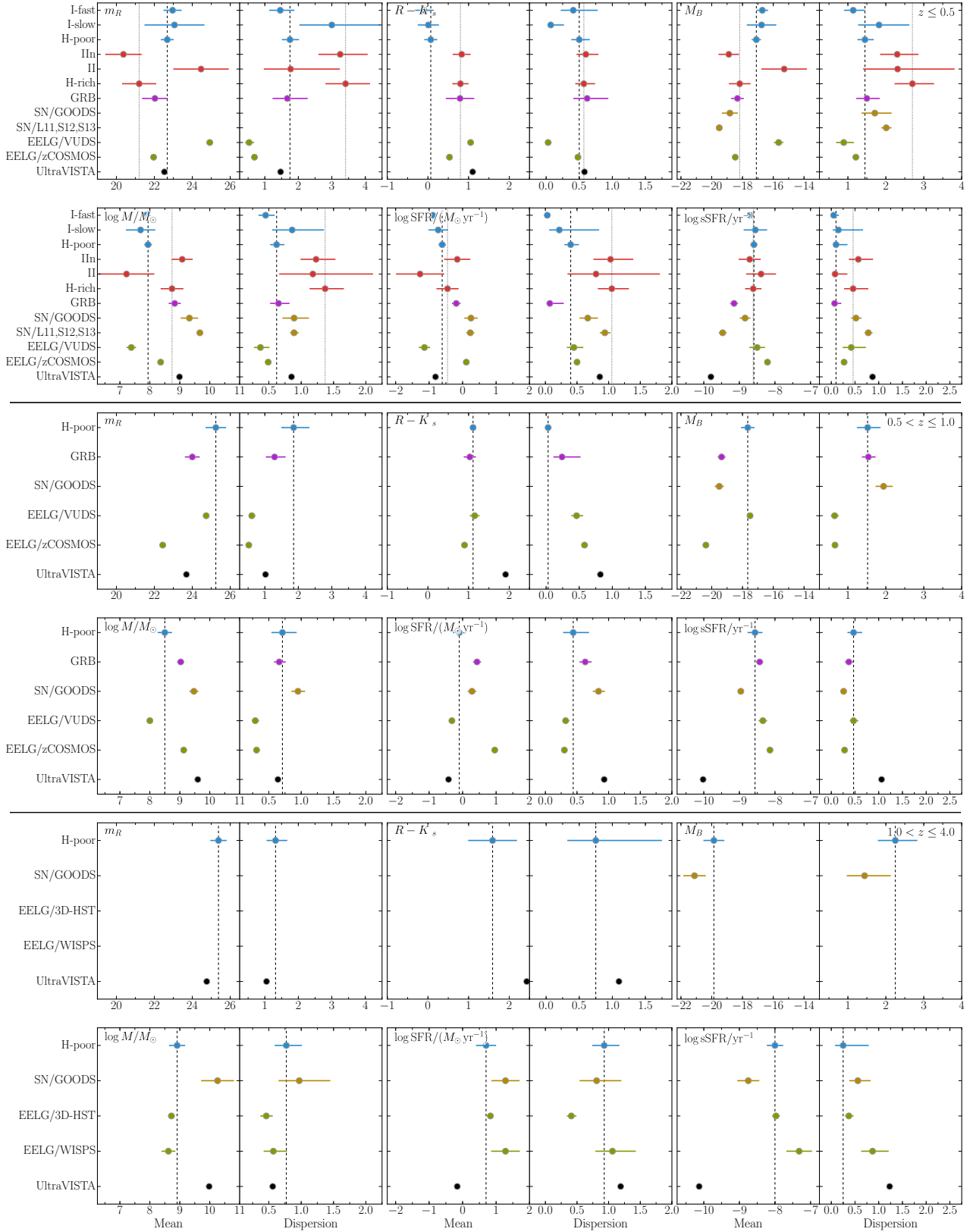


Figure D1. Statistical properties of the SLSN host galaxy populations and of the comparison samples. Top: $z \leq 0.5$. Centre: $0.5 < z \leq 1.0$. Bottom: $1.0 < z \leq 4.0$. For each property, the mean and the dispersion are displayed, as well as their uncertainties (for details see Sect. 3.4). The vertical lines indicate location of the H-poor (dashed) and H-rich (dotted) SLSN host populations in the diagnostics plots. Note, the exceptionally blue colours of SLSN-I hosts at $z < 0.5$ and huge dispersions of some SLSN-II host properties. The measurement values are listed in Tables 3 and D1.

Table D1. Statistical properties of GRB and SN host galaxies, EELGs and star-forming galaxies from the UltraVISTA survey per redshift bin

Sample	Number	Mean Redshift	m_R (mag)	$(R - K_s)$ (mag)	M_B (mag)	$\log M/M_\odot$	$\log \text{SFR}$ ($M_\odot \text{ yr}^{-1}$)	$\log \text{sSFR}$ (yr^{-1})
$z \leq 0.5$								
GRB	14	0.32	22.03 ± 0.68 (7) $1.67^{+0.61}_{-0.44}$	0.79 ± 0.35 (5) $0.62^{+0.32}_{-0.21}$	-18.33 ± 0.41 $1.50^{+0.34}_{-0.28}$	8.83 ± 0.20 $0.65^{+0.17}_{-0.13}$	-0.19 ± 0.13 $0.07^{+0.22}_{-0.05}$	-9.15 ± 0.11 $0.07^{+0.14}_{-0.04}$
SN								
<i>GOODS</i>	12	0.41	...	...	-18.82 ± 0.52 $1.71^{+0.44}_{-0.35}$	9.32 ± 0.29 $0.89^{+0.23}_{-0.18}$	0.25 ± 0.20 $0.67^{+0.16}_{-0.13}$	-8.84 ± 0.15 $0.52^{+0.12}_{-0.10}$
<i>L11, S12, S13</i>	105	0.05	...	...	-19.51 ± 0.20 $2.01^{+0.14}_{-0.13}$	9.67 ± 0.09 $0.89^{+0.07}_{-0.06}$	0.23 ± 0.12 $0.94^{+0.09}_{-0.08}$	-9.47 ± 0.11 $0.78^{+0.09}_{-0.08}$
EELG								
<i>VUDS</i>	9	0.34	24.92 ± 0.18 (11) $0.53^{+0.15}_{-0.12}$	1.05 ± 0.07 (11) $0.03^{+0.05}_{-0.02}$	-15.65 ± 0.31 $0.89^{+0.27}_{-0.20}$	7.38 ± 0.16 $0.37^{+0.14}_{-0.10}$	-1.14 ± 0.17 $0.45^{+0.15}_{-0.11}$	-8.50 ± 0.22 $0.42^{+0.31}_{-0.18}$
<i>zCOSMOS</i>	86	0.30	21.96 ± 0.07 (89) 0.69 ± 0.05	0.53 ± 0.05 (89) 0.48 ± 0.04	-18.47 ± 0.13 1.21 ± 0.09	8.36 ± 0.06 $0.49^{+0.05}_{-0.04}$	0.11 ± 0.06 0.50 ± 0.04	-8.21 ± 0.04 0.27 ± 0.03
UltraVISTA	26706	0.33	22.53 ± 0.01 1.47	1.10 ± 0.01 0.58	...	8.99 ± 0.01 0.85	-0.81 ± 0.01 0.86	-9.80 ± 0.01 0.87
$0.5 < z \leq 1.0$								
GRB	38	0.76	24.00 ± 0.39 (12) $1.29^{+0.33}_{-0.26}$	1.03 ± 0.15 (7) $0.24^{+0.28}_{-0.11}$	-19.36 ± 0.25 $1.54^{+0.19}_{-0.17}$	9.03 ± 0.12 $0.66^{+0.10}_{-0.08}$	0.43 ± 0.12 $0.63^{+0.10}_{-0.09}$	-8.43 ± 0.10 $0.37^{+0.09}_{-0.08}$
SN								
<i>GOODS</i>	41	0.72	...	...	-19.51 ± 0.30 $1.94^{+0.24}_{-0.21}$	9.47 ± 0.15 $0.95^{+0.11}_{-0.10}$	0.28 ± 0.13 $0.84^{+0.10}_{-0.09}$	-8.96 ± 0.04 0.26 ± 0.03
EELG								
<i>VUDS</i>	21	0.65	24.73 ± 0.14 (19) $0.61^{+0.11}_{-0.09}$	1.15 ± 0.12 (19) $0.46^{+0.10}_{-0.08}$	-17.51 ± 0.14 $0.65^{+0.11}_{-0.10}$	8.00 ± 0.07 $0.29^{+0.06}_{-0.05}$	-0.32 ± 0.08 $0.32^{+0.06}_{-0.05}$	-8.34 ± 0.12 $0.47^{+0.10}_{-0.08}$
<i>zCOSMOS</i>	78	0.70	22.44 ± 0.05 (91) 0.52 ± 0.04	0.90 ± 0.06 (91) $0.58^{+0.05}_{-0.04}$	-20.38 ± 0.08 $0.66^{+0.06}_{-0.05}$	9.13 ± 0.04 0.31 ± 0.03	0.96 ± 0.04 0.30 ± 0.03	-8.14 ± 0.04 0.28 ± 0.03
UltraVISTA	52689	0.77	23.69 ± 0.01 1.02	1.91 ± 0.01 0.82	...	9.60 ± 0.01 0.64	-0.42 ± 0.01 0.93	-10.02 ± 0.01 1.06
$1.0 < z \leq 4.0$								
SN								
<i>GOODS</i>	5	1.16	...	...	-21.12 ± 0.73 $1.44^{+0.69}_{-0.47}$	10.26 ± 0.55 $0.97^{+0.48}_{-0.32}$	1.28 ± 0.42 $0.81^{+0.39}_{-0.27}$	-8.75 ± 0.31 $0.56^{+0.27}_{-0.18}$
EELG								
<i>3DHST</i>	22	1.75	...	...	...	8.72 ± 0.11 $0.46^{+0.10}_{-0.09}$	0.83 ± 0.10 $0.41^{+0.08}_{-0.07}$	-7.97 ± 0.11 $0.37^{+0.10}_{-0.08}$
<i>WISPS</i>	7	1.62	...	...	...	8.62 ± 0.23 $0.57^{+0.21}_{-0.15}$	1.28 ± 0.43 $1.06^{+0.37}_{-0.27}$	-7.32 ± 0.36 $0.87^{+0.34}_{-0.24}$
UltraVISTA	70413	1.60	24.76 ± 0.01 1.05	2.43 ± 0.01 1.10	...	9.98 ± 0.01 0.56	-0.16 ± 0.01 1.19	-10.13 ± 0.01 1.23

Note. — Similar to Table 3. The first row of each element shows the mean value and its error and the second row the standard deviation of the sample. The SFRs and sSFRs were extracted from the SED modelling and are corrected for reddening.

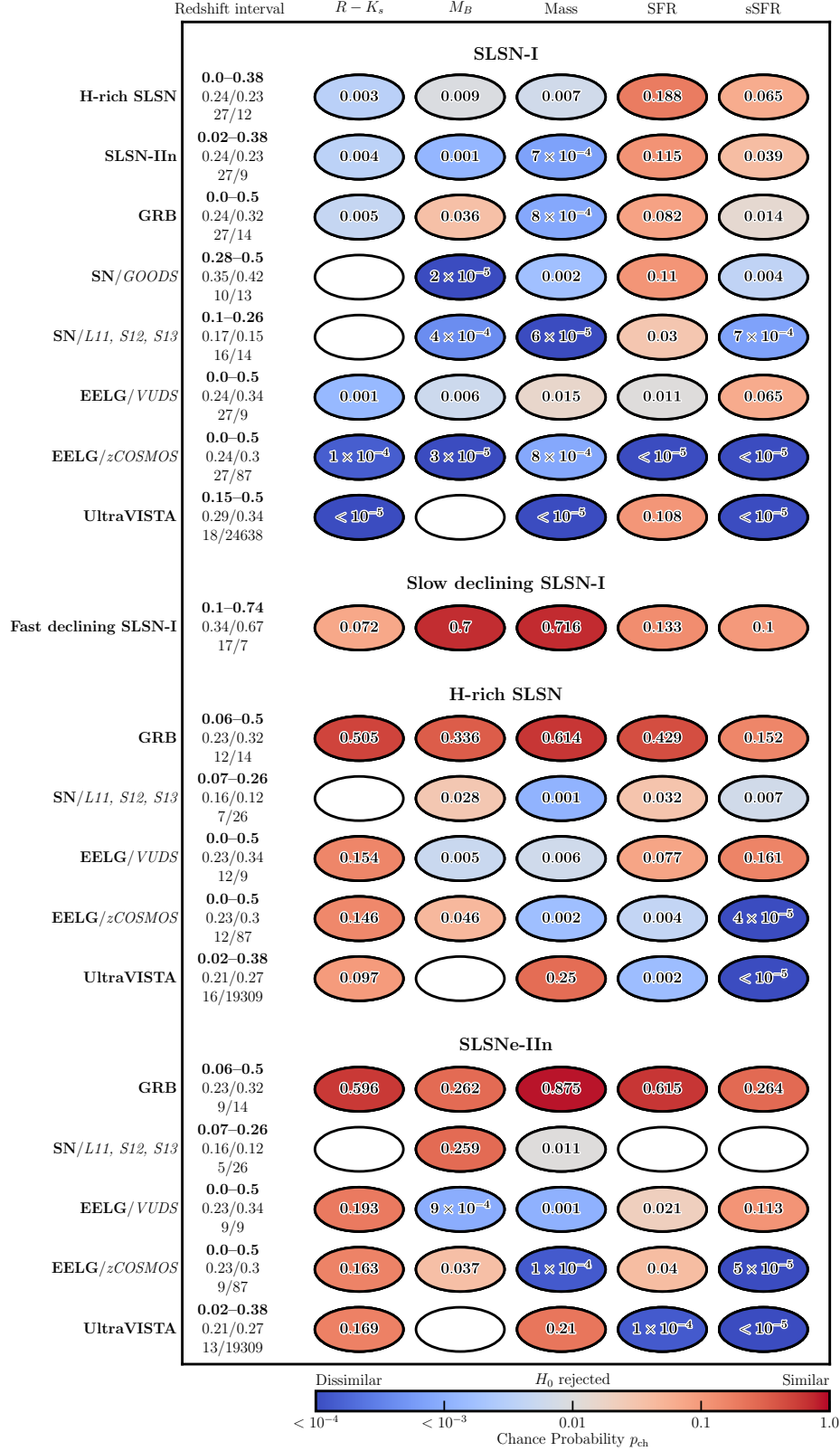


Figure D2. Statistical tests between SLSN host galaxies and different galaxy populations at $z < 0.5$. Redshift column: The first line shows the redshift range. The second line shows the mean redshifts of the individual sample and the last line the size of each sample. The values in the ellipses are the chance probabilities of the two-sided AD tests. The diverging color scheme is centred at the chance probability of $p_{\text{ch}} = 0.01$ where we reject the null hypothesis that the two samples have the same parent distribution. For each test we requested at least seven objects in each sample. Note, the comparison between slow- and fast declining H-poor SLSNe covers a slightly larger redshift interval.

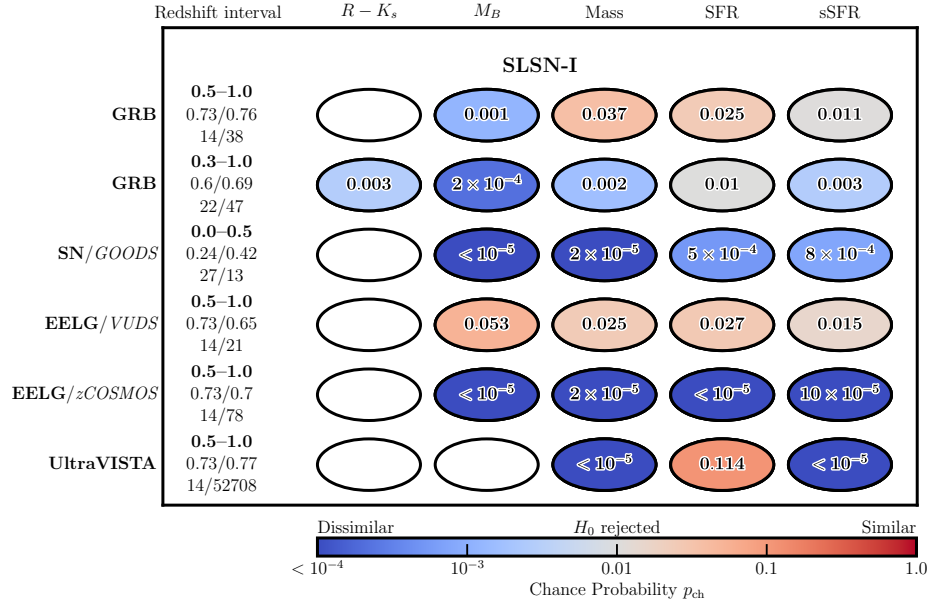


Figure D3. Same as Fig. D2 but for the redshift interval $0.5 < z < 1.0$. Note, the GRB comparison includes two redshift intervals: $0.5 < z < 1.0$ and $0.3 < z < 1.0$. The differences in their p_{ch} values are primarily due to the different sample sizes.

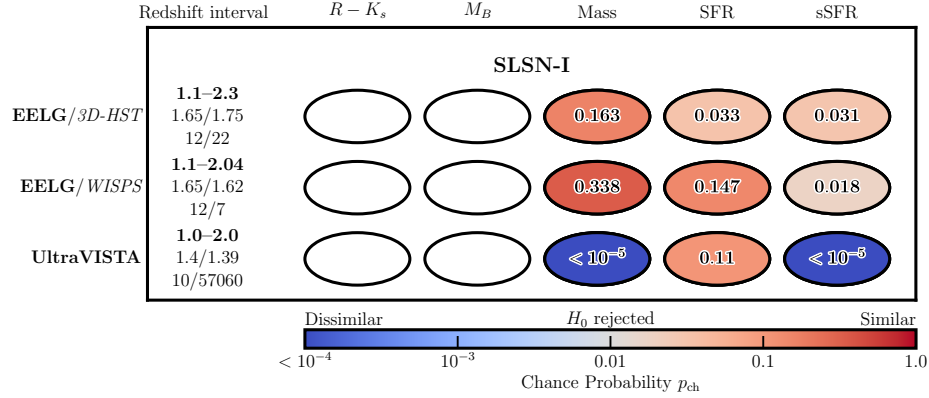


Figure D4. Same as Fig. D2 but for the redshift interval $1.0 < z < 4.0$.